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A SOIL ROAD IN ONONDAGA COUNTY, NEW YORK

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SOIL ROAD SURFACES

BY THE DIVISION OF TESTS, UNITED STATES BUREAU OF PUBLIC ROADS

Reported by C. A. HOGENTGLER, Senior Highway Engineer



FIGURE 1.—A SAND-CLAY SURFACE IN MUSCOGEE COUNTY, GA.

SOIL is the oldest and probably the most used of all engineering materials. However, substantial contributions to our present knowledge of soils date only from the very recent time when the importance of the physical character of the soil and the effect of surface tension of contained moisture were first recognized.

The first studies in soil physics were inaugurated for the purpose of identifying properties important in agriculture and geology. Tests of physical properties developed in these studies were used in identifying topsoils suitable for use in road surfaces. Later these tests were used in classifying subgrades with respect to performance in supporting road surfaces. More recently they became the basis of research in soil mechanics and now they are being used in establishing the fundamental principles and construction procedures in the new field of soil stabilization.

PERFORMANCE OF SOILS DEPENDS UPON THE CHARACTER AND GRADING OF THE CONSTITUENTS

Milton Whitney in 1892, then chief of the Weather Bureau, first explained in detail the effect of surface tension in contracting, expanding, and supplying cohesion in soils.¹ He thus furnished the basis for the present method of soil identification by means of physical characteristics.

In 1898 Dr. George E. Ladd advanced two additional basic guides: That silt consists of bulky grains and clay of scalelike particles, and that shrinkage of soil is caused by surface tension when water recedes in the soil capillaries.²

Simple tests used in the present routine testing procedure to disclose the physical properties of road soils

were devised by A. Atterberg, a Swedish scientist, as early as 1911.³ However, it remained for A. C. Rose, of the United States Bureau of Public Roads, in 1924, to first correlate road surface performance with the results of tests devised to disclose the physical properties of subgrade soils.⁴

The publication of a treatise on soil mechanics by Charles Terzaghi in 1925⁵ marks another important step in the progress of soil studies. For the first time mathematical formulas were available for determining quantitatively the effects of surface tension on the performance of soils.

Appropriate tests based upon Terzaghi's theory of consolidation opened the way to determining properties such as compressibility, expansibility, and permeability. With such information, furnished by tests on small samples in the laboratory, it became possible to estimate the ultimate settlements to be expected in foundations constructed on soft undersoils and also the rate at which they would be likely to occur.

Investigations begun in 1906 by Dr. C. M. Strahan,⁶ then county engineer of Clark County, Ga., mark the first consistent effort to correlate the performance of topsoils in road surfaces with their gradings as determined by mechanical analyses.

The name "topsoil" was applied to soil skimmed from the surface of fields to shallow depths. It was thought that during long cultivation such deposits had undergone weathering, water separation, and the probable

¹ Über die physikalische Bodenuntersuchung, und Über die Plastizität der Tone, by A. Atterberg, Internationale Mitteilungen für Bodenkunde, vol. 1, 1911; see also Adaptation of Atterberg Plasticity Tests for Subgrade Soils, by A. M. Wintermyer, Public Roads, vol. 7, no. 6, August 1926.

² Practical Field Tests for Subgrade Soils, Public Roads, vol. 5, no. 6, August 1924; and Present Status of Subgrade Studies, Public Roads, vol. 6, no. 7, September 1925.

³ Erdbaumechanik, by Charles Terzaghi, Vienna, 1925.
⁴ Research Work on Semi-Gravel, Topsoil, and Sand-Clay, and Other Road Materials in Georgia, by Dr. C. M. Strahan, Bulletin of the University of Georgia, vol. 22, no. 5a, June 1932.

⁵ Weather Bulletin No. 4, U. S. Department of Agriculture.

⁶ Geological Phenomena Resulting from the Surface Tension of Water, by George E. Ladd, American Geologist, vol. 22, no. 5, November 1898. Clays of Georgia, by George E. Ladd, Geological Survey of Georgia, Bull. No. 6-A, 1898.

influence of organic acids which gave them their superior consistency and binding stability.

In Dr. Strahan's work samples were obtained from short stretches of existing roads where firmness and water-resisting qualities were noted in contrast with ordinary conditions of dirt roads. Fifty or more counties were visited during the study. The data from laboratory tests on the samples collected were related to the road behavior under varying weather conditions and traffic, and the conclusions reached became the basis for selecting materials and the adoption of laboratory standards.

The first statement of the probable mode of action of road soils under traffic and weather was prepared by Dr. Strahan in 1914 for distribution at the Fourth American Road Congress held that year in Atlanta, Ga.

After the passage of the Federal-aid act in 1916, the first conference of State highway testing engineers and chemists was called to meet in Washington, February 1917, under the auspices of the Bureau of Public Roads, to consult concerning standards and specifications for the various road building materials. A committee⁷ on semigravel, topsoil, and sand-clay aggregates recommended gradings for three classes of topsoils, hard or class A, medium or class B, and soft or class C, and the recommendations were adopted.

The gradings adopted remained unchanged in subsequent reports by Dr. Strahan, the last of which was published in *Public Roads*, September 1929.

ROAD-SOIL GROUPINGS AND THEORY OF STABILITY DEVELOPED

A report⁸ resulting from a combined attack on the road-soil problem by the soil physicist, the pedologist, and the geologist, cooperating with the highway engineer, published in 1929, added two new developments on the subject of soil studies which by this time was rapidly growing into proportions having all the semblance of a new branch of science. They were:

1. A procedure for testing soils in the laboratory and classifying them in groups according to a fixed classification schedule. All the soils in a given group have similar characteristics with regard to drainage and are similar in their effect on road design.
2. A mathematical theory of stability which gave some conception of the relative influence of such factors as the granular fraction, the cohesive fraction, the moisture content of the soil and the weight and the load distribution properties of the road surface.

The soil grouping proposed had the unique feature of indicating performance under existing conditions of traffic, construction, and climate. In this it differed from the older classifications of the geologist based upon geological origin and that of the agronomist based upon the pedologic development.

The development of this grouping was in response to the general question "What conspicuous performances of soil are of interest in the design, construction, and maintenance of highways?" Answers to this question form the basis of the group designations. Thus one group includes soils of high stability generally as distinguished from soils of other groups which may have high stability only under unusually moist conditions on one hand or unusually dry conditions on the other.

The groupings provide for separate classification of soils which are apt to heave detrimentally due to frost and the granular soils in which such trouble is not to be expected, and also the elastic soils in which special

methods of preparation are required to eliminate detrimental rebound after consolidation and the compressible soils not characterized by such rebound.

In yet other groups are the soils which require special treatment in order that detrimental shrinkage or swell of the subgrade be prevented, and also the peaty and muck soils which give low support.

Within the groups of soils subject to frost heave there is the further distinction between those soils for which the corrective measure is drainage, those on which bituminous surface treatments or other impervious coverings prove beneficial and those which, because of high capillary properties, can be improved only by means of thick coverings of granular material.

The ultimate aim of this classification is to have each group designation signify characteristic performance of soils, the methods of improving performance, and the corresponding road surface requirements.

In this connection the gradings suggested by Dr. Strahan, modified in the light of new experience and supplemented by the results of simple physical tests, were adopted for use in the identification of the quality of soil mixtures and to disclose the effect of admixtures in improving the quality of the poorer soils.⁹

THE THEORY OF STABILITY DISCUSSED

Soil movement during loss of stability or rutting is illustrated by figure 2. It is assumed that the load is applied for an indefinite length over a width of $2b$. For deformation under the load to occur, the section A must shear along some plane such as S and displace laterally as indicated in figure 2, B. But for this to occur, the adjacent section marked C must shear along some surface as S' and, in consequence, displace upward forming a bulge adjacent to the loaded area as shown in figure 2, C.

Actually the surfaces S and S' may be parts of a continuously curved surface but, for mathematical treatment, they may be considered as separate plane surfaces without introducing a large error.

If rutting is to be prevented, the prism C must resist displacement sufficiently to prevent the lateral bulging of the prism A. This may be accomplished by two means, separately or in combination. The shear strength along the planes S and S' must be sufficiently high to prevent sliding of the prisms, or sufficient weight must be placed adjacent to the loaded area to prevent the upward bulging of the prism C.

Friction between the granular particles, combined with the stickiness or cohesion furnished by clay or water films in the binder, control the shear strength of the soil. The road surface furnishes the weight adjacent to the loaded area.

Table 1 gives theoretical supporting values for conditions of load as shown in figure 2, and serves to illustrate the effect of internal friction and cohesion under varying moisture conditions. These data disclose that the supporting value of clay soils may drop from as much as about 12,000 pounds per square foot to less than 400 pounds per square foot with change

⁷ The committee consisted of C. M. Strahan, of Georgia; C. B. Scott, of Virginia; and I. B. Mullis, of North Carolina.

⁸ Interrelationship of Load, Road and Subgrade, by C. A. Hogentogler and Charles Terraghi, *Public Roads*, vol. 10, no. 3, May 1929.

⁹ See Interrelationship of Load, Road, and Subgrade, by C. A. Hogentogler and Charles Terraghi, *Public Roads*, vol. 10, no. 3, May 1929, p. 10; The Subgrade Soil Constants, Their Significance, and Their Application in Practice, Part 2, by C. A. Hogentogler, A. M. Wintermyer, and E. A. Willis, *Public Roads*, vol. 12, no. 1, July 1931, p. 134; Tar Surface Treatment of Low Cost Roads, *Public Roads*, vol. 13, no. 1, March 1933, p. 13.

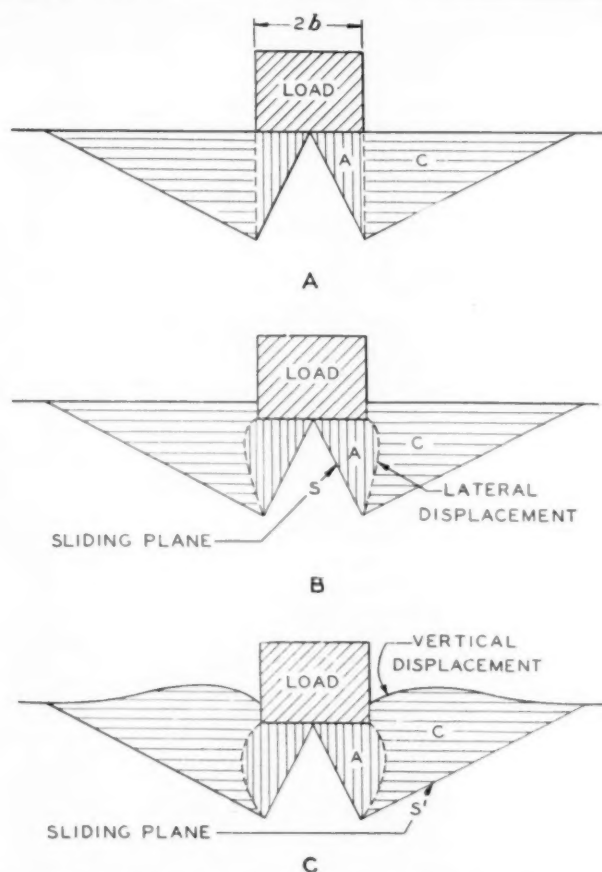


FIGURE 2.—SHEAR PLANES ALONG WHICH LATERAL DISPLACEMENT OF SOILS OCCURS.

from the dry or damp to a soft or almost liquid state. Since the computations are based on the assumption that the load is applied to a narrow strip of indefinite length, the conditions are different from those of a wheel load. The values given serve to illustrate the effect of moisture on stability and are not suggested as a basis for road design.

While the stability of a cohesionless sand may be less than 300 pounds per square foot and that of a fairly stiff clay about 5,000 pounds per square foot, these two materials properly combined may have a supporting value of more than 17,000 pounds per square foot. As a matter of fact, only the cohesion of an almost liquid clay, about 130 pounds per square foot, is required to increase the supporting value of cohesionless sand from 270 pounds per square foot to 2,500 pounds per square foot.

The essential consideration in stabilization is to provide the combination of internal friction and cohesion required to furnish the soil with high shearing strength. This quality is necessary in road surfaces, subgrades, and bases for thin wearing courses. Regardless of the methods used to provide high shearing strength, the success of the efforts will depend upon the permanent adhesive strength which can be developed by the minute films, whether of water or of special chemical substances which connect the soil particles.

It is well known that the denser the soil, the greater is its stability. This is due only in part to the greater mechanical bond resulting from the closer association of grains. Of more importance is the fact that the thin-

TABLE 1.—Influence of internal friction and cohesion upon the stability of soils

| Soil type | Cohesion c | Angle of internal friction ϕ | Supporting value, q^1 | Cohesion c required to increase q to 2,500 pounds per square foot |
|-------------------------------|------------------|-----------------------------------|-------------------------|---|
| | Lbs. per sq. ft. | Degrees | Lbs. per sq. ft. | Lbs. per sq. ft. |
| Clay, liquid..... | 100 | 0 | 400 | |
| Clay, very soft..... | 200 | 2 | 860 | |
| Clay, soft..... | 400 | 4 | 1,850 | |
| Clay, fairly stiff..... | 1,000 | 6 | 4,970 | |
| Clay, very stiff..... | 2,000 | 12 | 12,490 | |
| Sand, dry..... | 0 | 34 | 270 | 131 |
| Cemented sand and gravel..... | 1,000 | 34 | 17,340 | |

¹ Computations based on assumptions that weight of the soil equals 100 pounds per cubic foot and width of loaded area equals 3 inches.

ner the connecting films the greater is their adhesive force. Until the characteristics of materials in film phase are understood, the enormous cohesion furnished by films of molecular thicknesses cannot be visualized nor the full possibilities of soil stabilization realized.

To facilitate an understanding of the colloidal phenomena which serve as a basis for the intelligent formulation of methods of stabilization, there is presented the following digest, mainly from Bancroft¹⁰ on the general theory of colloid chemistry as it applies to the cohesion furnished by films of submicroscopic dimensions in the soil.

MOISTURE IN FILM PHASE CAN GREATLY INCREASE SOIL STABILITY

All solids tend to adsorb or condense on their surfaces any gases or vapors with which they are in contact. Adsorption is specific and varies with the nature of the gas and of the adsorbing solid. With the same solid and the same gas the amount of adsorption is greater the higher the pressure of the gas and the lower the temperature.

If a liquid is adsorbed at a solid surface, it forms a liquid film there and thus wets the solid. For a liquid to wet a solid in the presence of air the liquid must be adsorbed more strongly than the air and must displace the air.

During a period of drought, drops of rain will often roll along the dust without wetting it. Even in the case of a shower the dust may be only wetted to a depth of less than $\frac{1}{4}$ inch. This has been shown to be due to the adsorbed air on the surface of the solid. Any treatment which cuts down the amount of adsorbed air makes the dust more easily wetted.

Some conception of the character of gas films is furnished by the thought that the transition of a pure liquid to its own vapor is not abrupt but that over a narrow range all the densities intermediate between those of vapor and of the liquid actually occur. One authority estimates the transition film for carbon dioxide at 20° C. to be 3 molecules or about 3 ten-millionths of an inch thick.

Williams¹¹ suggested in 1920 that the first layer of an adsorbed gas vapor may be under a pressure of as much as 10,000 atmospheres and have a corresponding density. From the first layer outward the density decreases to that of the liquid in bulk in the outermost layer.

¹⁰ Applied Colloidal Chemistry by W. D. Bancroft, McGraw-Hill Book Co., Inc., 1932.

¹¹ Proceedings of the Royal Society, vol. 98A, 1920, p. 223.

In like manner, the character of water changes with the size of the particle. Drops $\frac{1}{40,000}$ of an inch to about $\frac{1}{1,000,000}$ inch in size, when suspended in the air, appear as fog if you walk through them and as a cloud if you look at them from a distance. Under electrical stress they coalesce to form raindrops at sizes of about $\frac{1}{300}$ inch to $\frac{1}{4}$ inch in size, which eventually become moisture films in soils.

So long as the soils are in a liquid or a plastic state, the films have in general the evaporation and freezing characteristics and the surface tension of water in bulk. When drying or mechanical compaction reduces the density of the soil below that at the plastic limit, the boiling point of the film rises, the freezing point lowers, and the surface tension increases so that these films become somewhat tougher than water in bulk.¹² This causes the soil to change from a plastic to a semisolid material. In thicknesses below $\frac{1}{1,000,000}$ of an inch, the films behave, according to Terzaghi, like semisolid substances.¹³

The very fine vapor films have an adhesive power so great that they cannot be removed from glass by heating at a temperature up to 500° C. This high tenacity is utilized in the manufacture of frosted glass for use in office doors and windows. Rather thick glass is first coated with gelatine or glue. As the glue loses moisture it contracts, and the power of the gelatine is so great that it tears away the surface of the glass itself, chipping it into fern-like patterns. A brittle glue will give a different pattern from a tough glue, and the addition of salts also modifies the patterns.

That the properties of the minute moisture films approach those of semisolids instead of liquids accounts for the fact shown by Keen¹⁴ that samples of sand grains with a binder of clay colloids can be 19 times as strong in compression as similar sand grains with an equal proportion of portland cement binder.

The theory of adhesion depends in part on the fact that the cementing material adheres strongly to the two surfaces and hardens there. For a given adhesive film and given materials the thinnest film gives the strongest joint. The thickness of films depends upon both the adhesive and the materials to be cemented. A slight change in the electrolytic properties of the latter is sufficient to cause a considerable variation in the thickness of the adhesive film and consequently in the strength of the resulting mixture of adhesive and aggregate.

According to Bancroft, Pettijohn¹⁵ found about $\frac{1}{1,000,000}$ of an inch for the maximum thickness of a water film on pearls made from one type of glass and $\frac{10}{1,000,000}$ of an inch for pearls made from another type. With river sand the estimated thickness varied from $\frac{20}{1,000,000}$ with 10-mesh sand to $\frac{1}{1,000,000}$ of an inch with 60-mesh sand.

Methods utilized to obtain or maintain adhesive film strength in soils may be listed as follows:

1. Use of graded materials with granular material and binder of such character and in such proportions as to furnish the required pore size.
2. Treatment of road surface mixtures with deliquescent chemicals to stabilize the moisture content.

¹² Simplified Soil Tests for Subgrades and their Physical Significance, by Charles Terzaghi, Public Roads, vol. 7, no. 8, October 1926, p. 154.

¹³ Physical Review, vol. 16, 1920, p. 56.

¹⁴ The Physical Properties of the Soil, by Bernard A. Keen, Longmans Green and Co., 1931.

¹⁵ Journal of the American Chemical Society, vol. 41, 1919, p. 477.

3. Densification of soil at optimum moisture content or treatment with chemical electrolyzers to facilitate the wetting of soil grains and decrease the thickness of the moisture films; use of bituminous materials to increase the cohesion and eliminate those properties of clay and colloids productive of detrimental volume change; and use of crystallizers to form water-resistant connecting films by hydration or base exchange.

4. Stabilization of the moisture content by waterproofing the soil with impervious surface treatments of bituminous materials.

WELL-GRADED MATERIALS HAVE CERTAIN ESSENTIAL FEATURES

Certain soils can be used to make a firm and hard road surface, capable of supporting the heaviest loads after long rains, free from mud or excessive dust, and which will carry traffic in both wet and dry weather without undue injury. Figure 1 is an example of such a surface.

Such materials are designated as hard or class A by Dr. Strahan and consist of coarse aggregate and soil mortar. The coarse aggregate is that portion retained on the no. 10 sieve and includes particles of natural gravel, supplemented when necessary with crushed stone or slag. Generally the largest particles should not exceed about 1 inch.

The mortar includes coarse sand or other granular material passing the no. 10 sieve and retained on the no. 60 sieve; fine sand passing the no. 60 sieve and retained on the no. 270 sieve; silt particles between 0.05 and 0.005 mm (0.002 inch to 0.0002 inch) in diameter; clay particles smaller than 0.005 mm in diameter; and moisture.

The coarse aggregate and coarse sand furnish structural strength and hardness; fine sand adds an embedment support to the coarse sand; silt acts as a filler to prevent the granular particles from rocking; and clay and colloidal particles provide pores minute enough to cause connecting moisture films which produce high cohesion.

Dr. Strahan called attention to the importance of the soil mortar as follows: "In judging these materials (road soils) full emphasis should be placed upon the soil mortar, i. e., material below no. 10 sieve. Weak soil mortars even with large amounts of coarse material often do not give proper stability under traffic."

In Dr. Strahan's reports clay is used to designate particles less than about 0.02 millimeter in diameter; silt, those particles with diameters between 0.02 and 0.07 millimeter; and sand, those particles larger than 0.07 millimeter in diameter.

In more recent work new size ranges have been adopted for several reasons:

1. The new sizes represent fractions having special physical significance. Particles larger than 0.05 millimeter have neither cohesion nor capillarity in appreciable amount; particles varying between 0.05 and 0.005 millimeter have considerable capillarity but little or no cohesion; and only particles smaller than about 0.005 millimeter can furnish cohesion.

2. The new sizes are used by the Bureau of Chemistry and Soils of the United States Department of Agriculture. The use of the same size ranges in highway work facilitates the use of the great amount of published information on soil surveys made by that bureau in which the mechanical analysis plays an important part.

3. Prior to the development of the hydrometer method of analysis, the determination of the complete grading of the subsieve fraction was so laborious as to be impractical as a routine test for highway purposes. With the hydrometer method the grading according to the new sizes may be determined with no greater effort than was required for the determination of the grading by the old method of decantation.

Experience with soils indicates that they are stable only when they contain constituents which produce the following:

1. A certain total of seating and embedment stability together with the density required to resist traffic pressures and impacts.

2. An internal bond developed from interlocking grains and capillary moisture forces sufficient to cause the coarser sizes of sand and the coarse aggregate to have high stability during wet weather when the cohesion furnished by the clay may be greatly reduced.

3. Sufficient cohesion in the binder to cement the sand and silt when in a dry or almost dry condition and thus maintain the integrity of the surface during dry weather.

4. A surface which maintains constant volume, that is, there should not be so much clay that its expansion by water will break the seating and embedment bond of the granular particles.

5. Rapid evaporation to prevent the accumulation of capillary moisture from the subgrade beneath and active percolation to dispose of the rain water which may collect on the roadway in spite of efforts to maintain a smooth surface for the prompt removal of water.

The design of soil mixtures to provide these conditions is now based on the grading of the entire soil sample as determined by mechanical analyses, and on the binding properties of the fines as disclosed by plasticity tests performed on the fraction of soil passing the no. 40 sieve.

Materials falling within the following composition limits, by weight, should produce good results:

| Passing— | Percent |
|--------------------|---------|
| 1-inch screen..... | 10-100 |
| ¾-inch screen..... | 85-100 |
| No. 4 sieve..... | 55-85 |
| No. 10 sieve..... | 40-65 |
| No. 40 sieve..... | 25-50 |
| No. 270 sieve..... | 10-25 |

The fraction passing the no. 270 sieve should be less than two-thirds of the fraction passing the no. 40 sieve. Depending upon moisture conditions as discussed below, the fraction passing the no. 40 sieve shall have a plasticity index between 1 and 15 and a liquid limit not exceeding 35 as determined by physical tests made according to the methods of the Bureau of Public Roads.¹⁷

As early as 1922 Dr. Straham called attention to the need for tests to disclose binding properties, suggesting that a highly colloidal clay in small amounts would evidently give adhesive strength equal to that produced by a large amount of less colloidal clay in a road soil mixture.

Another important indication was furnished by the work of the late Raymond Smith of the Ohio Department of Highways. Working with Prof. F. H. Eno of Ohio State University in constructing traffic-bound

roads, he found that the stabilizing of material consisting principally of rounded particles, was greatly facilitated by additions of crushed materials or granulated slag.

As an additional guide, the field moisture equivalents may serve to indicate the tendency of binders to soften under conditions producing high moisture contents. In this connection values of 20 and less, 20 to 25 and greater than 25 indicate respectively the best, the medium, and the poorer materials.

PLASTICITY TESTS INDICATE BOTH CAPILLARITY AND COHESION

All cohesive soils have capillary properties but all soils with capillarity do not have cohesion. Liquid limits up to about 20 or slightly more generally indicate sandy materials with negligible capillarity. The more the liquid limit exceeds this amount the greater is the capillarity of the material. The plasticity index indicates the cohesion of materials but does not indicate their capillarity. Therefore the greater the plasticity index for equal liquid limits, the greater the cohesion of the material.

The properties of a mixture consisting largely of a relatively inert material such as ground quartz may be considerably changed by admixtures. As more active constituents are admixed the properties become those of the highly capillary diatoms, the moderately cohesive kaolin or the highly plastic colloidal bentonite. There are definite relationships between the test results and the percentages of the constituents which furnish the characterizing properties of soils. This is illustrated in figure 3.

The relationships between the liquid limits, *LL*, the plasticity indexes, *PI*, and the percentages of the active constituents, *P*, in mixtures of active materials and inert quartz are as follows:

For diatoms, $PI=0.21P=0.19(LL-18)$.

For kaolin, $PI=0.15P=0.71(LL-18)$.

For bentonite, $PI=3.3P=1.0(LL-18)$.

If any particular amount of cohesion is desired, say that indicated by a plasticity index of 5, the admixture according to these formulas may be 24 percent of diatoms, 33 percent of kaolin, or 1.5 percent of bentonite. The corresponding capillarities will be those indicated by a liquid limit of 44 for the mixture containing diatoms, 25 for the kaolin mixture, and 23 for the bentonite mixture.

In like manner the percentage of soil binder together with the accompanying capillarity to produce a desired plasticity can be determined by means of data furnished by the plasticity tests. The amount of inert material required to reduce excessively high plasticity can also be determined from similar data.

Generally plasticity indexes of about 3 or less indicate sufficient binder cohesion for use in road construction under unusually wet conditions; 4 to about 8, under conditions of average moisture; and 9 to 15 inclusive, only under dry or arid conditions. Plasticity indexes exceeding 15 indicate soils not suitable for road surfacing.

The presence of the undesirable micaceous, diatomaceous, peaty, or other organic substances is indicated when the liquid limit is greater than $1.6PI+14$.

The more the liquid limits exceed this value the more unsatisfactory the soil binder is apt to be due to detrimental sponginess and capillarity. Such properties will not be present in detrimental amount when the liquid limit does not exceed about 35.

¹⁶ Material of greater maximum size can be used under certain conditions but the largest aggregate should never exceed ¼ the thickness of the stabilized layer and not more than 10 percent of the material should exceed 1 inch.

¹⁷ Procedures for Testing Soils for the Determination of the Subgrade Soil Constants, by A. M. Wintermyer, E. A. Willis, and R. C. Thoreen, Public Roads, vol. 12, no. 8, October 1931.

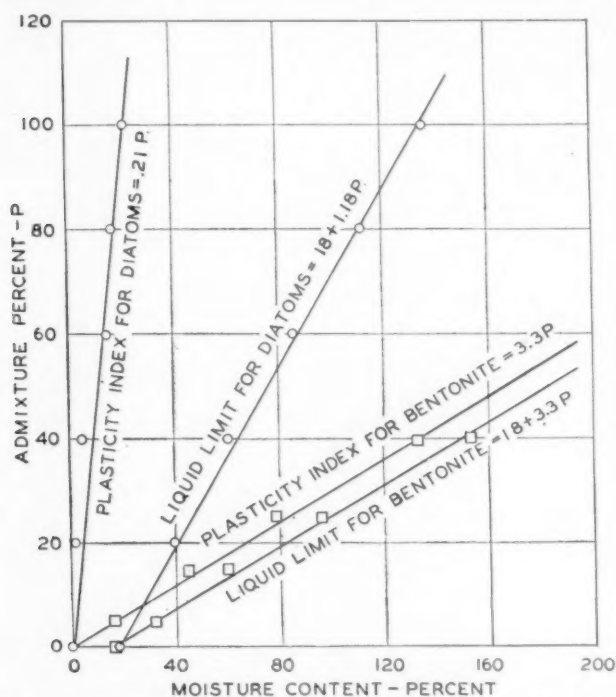


FIGURE 3.—RELATION BETWEEN PERCENTAGE OF ADMIXTURE OF INERT MATERIAL AND PLASTICITY LIMITS.

DELIQUESCENT SUBSTANCES USED TO PREVENT EXCESSIVE LOSS OF MOISTURE IN DRY WEATHER

Absence of moisture films from soil road surfaces causes dust and raveling; too much moisture causes rutting. The dryer a road surface becomes as a result of evaporation, the wetter a rain will make it. This is because extreme dryness causes small cracks and fissures to form in the clay binder through which rain water may enter and soften the interior of the road surface. Fissures do not form in damp surfaces of properly selected constituents and water will be shed from the surface without injurious effect.

Dampness of surface is desirable for another reason. All types of topsoil, gravel, traffic-bound and even water-bound macadam road surfaces acquire their final consolidation through compaction by traffic during what might be termed a period of seasoning following construction. When the surface is dry during this period the mineral binder powders under traffic and permits raveling of the surface, which requires extensive patching of the macadams and maintenance by means of mulch on the other types.

If such surfaces can be maintained in a damp or slightly moist state the moisture films in the minute pores of the binder will prevent the separation of the granular particles and the shocks and blows produced by traffic become effective in gradually wedging the granular fragments into close association. The cohesion increases as the pores in the binder become smaller and finally the coarse aggregate, the sand, the filler, and the binder are formed into a stable, durable road structure.

Calcium chloride is the principal chemical used in this type of stabilization although common salt has been used to a limited extent in experimental sections.

As early as 1907, Austin Thomas Byrne¹⁸ discussed the use of sea-water and deliquescent salts for the suppression of dust.

¹⁸ *Treatise on Highway Construction*, 5th edition, by Austin Thomas Byrne, John Wiley and Sons, New York, 1907, pp. 901-911.

The writer used calcium chloride as a dust layer on short sections of macadam streets in Pennsylvania about 1912. The value of this substance as a dust layer for gravel roads was quite generally recognized by 1916.

Sodium chloride has not received as much attention as calcium chloride although its possibilities were suggested by R. H. Phillips in 1919.¹⁹ It was used in experiments on the Wendover cut-off in 1924²⁰ and in Nova Scotia in 1931.²¹

A report resulting from an investigation of calcium chloride as a dust palliative by the Highway Research Board,²² first suggested the possibilities of this chemical for stabilizing the moisture content of graded materials in low type roads. This investigation included observations and tests on experimental roads in South Carolina, Missouri, and Nebraska. Supplemental tests were made to obtain quantitative data on the rate of evaporation from treated and untreated soil samples, the effect of rewetting surface on the rate of evaporation and on the leaching of calcium chloride by moisture.

CHEMICAL TREATMENT USED TO PRODUCE HIGH SOIL DENSITY

A recent report by W. R. Collings and L. C. Stewart²³ gives the results of traffic tests on test roads. This investigation included tests of various combinations of soils in road sections constructed on a large indoor track on an earth subgrade.

The track was oval in shape with straight sections 120 feet long and 12 feet wide and banked curves of 40 feet radius on the ends. The individual test sections were 25 feet long and 10 feet wide. A sprinkling system and hot air blown over the road surfaces were used to produce wet and dry road conditions. Mixtures for the test sections were prepared by combining various proportions of natural silts, clay, and fine and coarse aggregates. The materials were thoroughly mixed and deposited on the subgrade. The compaction was obtained by operating trucks over the test sections. In all, there were 28 test sections included in this investigation. Encouraging results furnished by these large-scale experiments were followed by the construction of the so-called stabilized soil road surfaces in a number of States, with the largest mileages in Michigan, Indiana, and Onondaga County, N. Y.

The Highway Research Board's investigation disclosed, among other things, that calcium chloride placed upon the surface retards the evaporation of soil moisture and that the moisture film cohesion furnished by calcium chloride is more stable than that furnished by plain water. It also showed that during periods of low rainfall and high temperatures the sections treated with calcium chloride have the higher moisture content and that calcium chloride is retained best in compacted and undisturbed surfaces.

The primary reason for the decrease in rate of evaporation is the low vapor pressure of the calcium chloride. A layer of the solution on the surface of the soil particle may be conceived of as an effective semi-permeable blanket through which the moisture from

¹⁹ Salt-Marsh Sand Clay as a Road-Building Material, *Engineering News-Record*, vol. 82, no. 12, Mar. 20, 1919, p. 575.

²⁰ A Salt Dressing for Roads, *Kentucky Road Builder*, vol. 3, no. 10, Oct. 1924, p. 8.

²¹ Nova Scotia's Experience with Dust Layers, by Percy C. Black, *Canadian Engineer*, vol. 61, no. 13, Sept. 29, 1931, p. 94.

²² Report of Investigation of the Use of Calcium Chloride as a Dust Palliative, by Fred Burggraf, *Proceedings of the Twelfth Annual Meeting of the Highway Research Board*, Part 2, 1932.

²³ Stabilized Soil-Bound Road Surfaces Part 2: Traffic Tests of Trial Roads, by W. R. Collings and L. C. Stewart, *Engineering News-Record*, vol. 112, no. 23, June 7, 1934.

the soil has difficulty in reaching the surface where evaporation takes place.

The hygroscopic property of calcium chloride causes absorption of moisture from the air during periods of high humidity and also slows up the rate at which soils lose moisture.

The high density attained during compaction by traffic is indicated by dry weights of as much as 150 pounds per cubic foot, which have been observed for wearing courses treated with calcium chloride and common salt. Retention of the material in the highly compacted state accounts for the beneficial action of the chemical upon the preservation of the road material.

MOST STABLE SOIL MIXTURES CONTAIN COARSE MATERIAL

The plasticity constants and the grading of a number of soil mixtures are shown in table 2. Mixture no. 1 shows the requirements of good mixtures as suggested on page 277 of this report. Mixture no. 2 represents the requirements of good soil mortars, based upon Dr. Strahan's work²⁴ assuming a coarse aggregate content of 50 percent. No. 3 is typical of the mixtures used in the construction of stabilized roads in Washtenaw County, Mich., in 1933.

Mixtures 4 to 8 are soil mortars studied by Collings and Stewart²⁵ in their investigation of the stability of various mixtures and the use of calcium chloride under controlled truck traffic. Mixtures 9 to 13 are of the sand-clay gravel type from the same experiments and were considerably more stable than mixtures 4 to 8. This is in line with Dr. Strahan's findings: "When coarse material is added to a good soil mortar in appreciable amount (10 percent or more) the hardness and durability of the surface is increased and continues to increase until a full gravel-type surface is reached."

Mixtures 14 to 17 are from the report on investigations by Travers and Hicks of stabilized roads in Onondaga County, N. Y.²⁶ Additional investigations by Collings and Stewart²⁷ furnished data on mixtures 18 to 30. Mixture no. 40 is typical of surfacing material used by G. A. Rahn in Pennsylvania.

Of these 10 mixtures investigated by Collings and Stewart, only nos. 4, 5, 6, 9, and 10, which have some plasticity, are considered satisfactory for surfacing. Samples 14 to 17, inclusive, representative of satisfactory mixtures reported by Travers and Hicks, had somewhat more plasticity than the 5 satisfactory soils reported by Collings and Stewart.

Of the mixtures 18 to 39, inclusive, mixtures 23 and 24, with no plasticity, and mixtures 32, 33, 38, and 39 were the least resistant.

The manner in which local materials are selected for use in soil roads was excellently described by G. A. Rahn, of the Pennsylvania Department of Highways, before the 1934 convention of the American Society for

TABLE 2.—Plasticity and grading of typical soil-road materials

[All materials pass the 1-inch screen]

| Mixture no. | Liquid limit | Plasticity index | Passing— | | | | |
|-------------|--------------|------------------|----------------|---------------|---------------|---------------|---------------|
| | | | ¾-in. screen | No. 4 sieve | No. 10 sieve | No. 40 sieve | No. 270 sieve |
| | Percent | Percent 1-15 | Percent 85-100 | Percent 55-85 | Percent 40-65 | Percent 25-50 | Percent 10-25 |
| 1..... | 14-35 | 4-8 | | | 50 | 25-34 | 10-25 |
| 2..... | 20 | 6 | | 73 | 50 | 38 | 17 |
| 3..... | 16 | 1 | | | 100 | 75 | 16 |
| 4..... | 15 | 4 | | | 100 | 77 | 27 |
| 5..... | 15 | 1 | | | 100 | 73 | 22 |
| 6..... | 16 | 0 | | | 100 | 77 | 13 |
| 7..... | 17 | 0 | | | 100 | 76 | 7 |
| 8..... | 17 | 4 | 100 | 72 | 39 | 25 | 12 |
| 9..... | 15 | 3 | 100 | 62 | 40 | 29 | 16 |
| 10..... | 13 | 0 | 97 | 53 | 39 | 22 | 11 |
| 11..... | 13 | 1 | 100 | 78 | 56 | 33 | 13 |
| 12..... | 12 | 0 | 100 | 69 | 43 | 20 | 10 |
| 13..... | 8 | 8 | 98 | 63 | 51 | 31 | 14 |
| 14..... | 7 | 7 | 98 | 73 | 63 | 39 | 23 |
| 15..... | 5 | 5 | 97 | 52 | 39 | 24 | 17 |
| 16..... | 7 | 7 | 98 | 65 | 53 | 28 | 10 |
| 17..... | 27 | 14 | 82 | 57 | 50 | 41 | 20 |
| 18..... | 22 | 11 | 82 | 58 | 51 | 43 | 20 |
| 19..... | 21 | 10 | 80 | 56 | 48 | 38 | 14 |
| 20..... | 17 | 5 | 79 | 54 | 46 | 36 | 11 |
| 21..... | 18 | 5 | 79 | 54 | 46 | 34 | 10 |
| 22..... | 0 | 82 | 57 | 50 | 38 | 10 | |
| 23..... | 0 | 79 | 54 | 45 | 34 | 6 | |
| 24..... | 28 | 15 | 95 | 68 | 54 | 46 | 24 |
| 25..... | 22 | 11 | 100 | 68 | 53 | 45 | 23 |
| 26..... | 21 | 10 | 100 | 77 | 59 | 48 | 22 |
| 27..... | 27 | 15 | 100 | 71 | 53 | 43 | 28 |
| 28..... | 22 | 11 | 94 | 64 | 47 | 39 | 16 |
| 29..... | 17 | 6 | 94 | 64 | 46 | 36 | 14 |
| 30..... | 27 | 15 | 100 | 70 | 50 | 38 | 18 |
| 31..... | 20 | 10 | 100 | 71 | 52 | 40 | 15 |
| 32..... | 18 | 6 | 94 | 65 | 47 | 56 | 10 |
| 33..... | 21 | 10 | 96 | 77 | 65 | 53 | 26 |
| 34..... | 27 | 15 | 96 | 77 | 66 | 58 | 36 |
| 35..... | 21 | 10 | 94 | 65 | 49 | 40 | 19 |
| 36..... | 27 | 15 | 94 | 63 | 48 | 41 | 24 |
| 37..... | 20 | 10 | 92 | 57 | 39 | 28 | 14 |
| 38..... | 28 | 15 | 92 | 52 | 33 | 28 | 17 |
| 39..... | 22 | 5 | 97 | 66 | 59 | 46 | 20 |
| 40..... | | | | | | | |

Testing Materials. In one case the soil of the original road was taken to the laboratory and on test was found to be a silt loam. Since stone screenings were available near the location of the road for use as a mixture, tests were made to determine the amount of admixture required to change the soil to the more stable A-2 type. With this information as a guide the screenings were applied to the old road and worked in until tests disclosed the proper amount had been added. Some time later calcium chloride was applied to the surface. The illustration, figure 4, was taken in April 1934 and shows the manner in which the stabilized road came through the winter in comparison with the side road which was not stabilized. Mixture 40 of table 2 is representative of the mixture used.

Calcium chloride is applied to soil surfaces at the rate of about one-half pound per square yard per inch of thickness of road surface and preferably should be mixed with the graded surfacing material. Indiana requires not less than three-fourths of a pound of common salt per square yard per inch of surface thickness with the additional requirement that the salt shall be applied in a solution of about 8 pounds of salt to 5 gallons of water.

The chemically treated surfaces are firmly bound and offer great resistance to raveling under traffic. Smoothness is maintained without the loose surface mulch often used on untreated gravel roads. In fact, the presence of mulch may act as an abrasive under the wheels of vehicles and thus prove detrimental.

²⁴ Subgrade Soil Constants, Their Significance, and Their Application in Practice, by C. A. Hogentogler, A. M. Wintermyer, and E. A. Willis, Public Roads, vol. 12, nos. 4 and 5, June and July, 1931.

²⁵ Report on Investigations of the Use of Calcium Chloride as a Dust Palliative, discussion by L. C. Stewart and W. R. Collings, Proceedings of the Twelfth Annual Meeting of the Highway Research Board, Part 2, 1932, p. 45; see also Improved Low Cost Soil and Gravel Roads, The Dow Chemical Co., 1933.

²⁶ Gravel Type Surfaces for Secondary Roads, by Ray B. Travers and W. B. Hicks, Proceedings of the Thirteenth Annual Meeting of the Highway Research Board, Part 1, 1933, p. 228.

²⁷ Stabilized Soil-Bound Road Surfaces, Part 2, Traffic Tests of Trial Roads, by W. R. Collings and L. C. Stewart, Engineering News-Record, vol. 112, no. 23, June 7, 1934.



FIGURE 4.—STABILIZED ROAD IN ADAMS COUNTY, PA., AT ITS JUNCTION WITH UNTREATED SIDE ROAD.

[A good mixture for the repair of areas in which pitting has occurred consists of aggregate under one-half inch in size, mixed with at least an equal weight of stable sand-clay. To insure that the patching materials will be moist enough to stick securely in the hole, the admixture of 100 to 150 pounds of calcium chloride per cubic yard is recommended.

Figures 5 and 6 illustrate steps in the construction of roads treated with deliquescent chemicals in Michigan. Figure 7 shows similar surfaces in Indiana.

PERMANENT DENSIFICATION OF SOILS A PROMISING BUT LITTLE-EXPLORED METHOD

The purpose of this type of stabilization is to produce a semisolid and dense soil-road surface which is not affected by moisture and is capable, when suitably surface treated, of serving a considerable volume of traffic. The method is suitable for use where only fine-grained soils abound as well as in those locations having granular materials and binder available for use in graded soil mixtures.

The idea of stabilizing soils by means of admixtures of other than soil materials is not new. Prof. F. H. Eno used both hydrated lime and portland cement as admixtures to improve subgrade soils in experimental sections in 1924 and 1925.²⁸

More recently, in 1929, Prof. Eno used salt, hydrated lime, calcium chloride, sodium silicate, kerosene, cold tar, crude oil, and used crankcase oil in addition to stone dust and granulated slag in experimental sections of subgrades of six traffic-bound roads in Ohio. The treatments were carried to a depth of 3 inches in the subgrade.²⁹

It was not until 1932, however, that the importance of densification in connection with the use of chemical admixtures began to be realized. From experiments performed at the Arlington laboratory of the Bureau of Public Roads it became evident that when soils were treated with such materials as portland cement, bituminous materials, etc., the stabilizers could best be distributed in fine-grained soils in the form of solu-

tions or emulsions. However, samples thus treated became porous upon drying due to the effect of the admixtures in reducing the shrinkage properties of the colloids. Thus the necessity of including mechanical compaction as part of the stabilizing procedure became evident. Experimentation was begun on procedures for compacting samples and determination of the properties of samples thus prepared.

Figure 8 shows an apparatus devised for bringing an entire sample, including the coarse fraction, to various degrees of consolidation. The apparatus is based on the principle of the sheepfoot roller, and it appears that compaction according to this principle will be desirable in construction. Samples having various degrees of consolidation have been tested for permeability, capillarity, stability, and shrinkage.

In 1933 a definite basis was established for the intelligent incorporation of admixtures in soils; a means was provided for determining the amount of compaction required; and a method was suggested for evaluating in the laboratory the relative stabilizing effects of the various admixtures. R. R. Proctor, of the Los Angeles Bureau of Waterworks, is largely responsible for these contributions.³⁰

In 1925 Milburn³¹ showed that there is an optimum binder content at which maximum density of bituminous mixtures may be attained, and in 1928 Jackson³² pointed out that concrete investigators accepted the conclusion that there is an optimum water-cement ratio for each portland cement concrete mixture. Proctor, in a series of reports, has shown that for every soil there is a moisture content at which maximum compaction can be obtained with a sheepfoot roller during construction. The extent of this compaction is readily ascertained by testing samples at different moisture contents under impacts of a standard tamper in the laboratory.

LABORATORY TESTS SHOW IMPORTANCE OF PROPER MOISTURE CONTENT IN PRODUCING MAXIMUM DENSITY BY COMPACTION

Figures 9, 10, and 11³³ illustrate the apparatus and the significance of the Proctor tests. The soil samples are compacted at different moisture contents in a one-thirtieth cubic-foot cylinder by the impact of a 5½-pound rammer in such a manner as to duplicate the force obtained by a sheepfoot roller in the field. The density of the compacted soil is computed from the actual weight of soil and the moisture content and expressed in pounds of soil per cubic foot. The bearing power of the compacted soil is determined for each moisture content by measuring the force needed to push a needle of known end-area into the soil at a speed of one-half inch per second.

Figure 9 shows the compacted fill material being tested with the plasticity needle. In the background is the type of sheepfoot roller used to compact the fill.

²⁸ Highway Subsoil Investigation in Ohio, by F. H. Eno, Engineering Experiment Station Bulletin No. 39, Ohio State University, 1928.

²⁹ Subgrade Drainage and Treatment by F. H. Eno, Proceedings Eleventh Annual Meeting of the Highway Research Board, 1931, p. 192.

³⁰ Fundamental Principles of Soil Compaction, by R. R. Proctor, Engineering News-Record vol. 111, no. 9, August 31, 1933; Field and Laboratory Determination of Soil Suitability, by R. R. Proctor, Engineering News-Record, vol. 111, no. 10, Sept. 7, 1933; Field and Laboratory Verification of Soil Suitability, by R. R. Proctor, Engineering News-Record, vol. 111, no. 12, Sept. 21, 1933; New Principles Applied to Actual Dam Building, by R. R. Proctor, Engineering News-Record, vol. 111, no. 13, Sept. 28, 1933.

³¹ A Deformation Test for Asphaltic Mixtures, by H. M. Milburn, Public Roads, vol. 6, no. 6, August 1925.

³² The Design of Pavement Concrete by the Water-Cement Ratio Method, by F. H. Jackson, Public Roads, vol. 9, no. 6, August 1928.

³³ These figures supplied by C. A. Hogentogler, Jr., soils engineer, Back Creek Earth Dam Project, U. S. Forest Service.

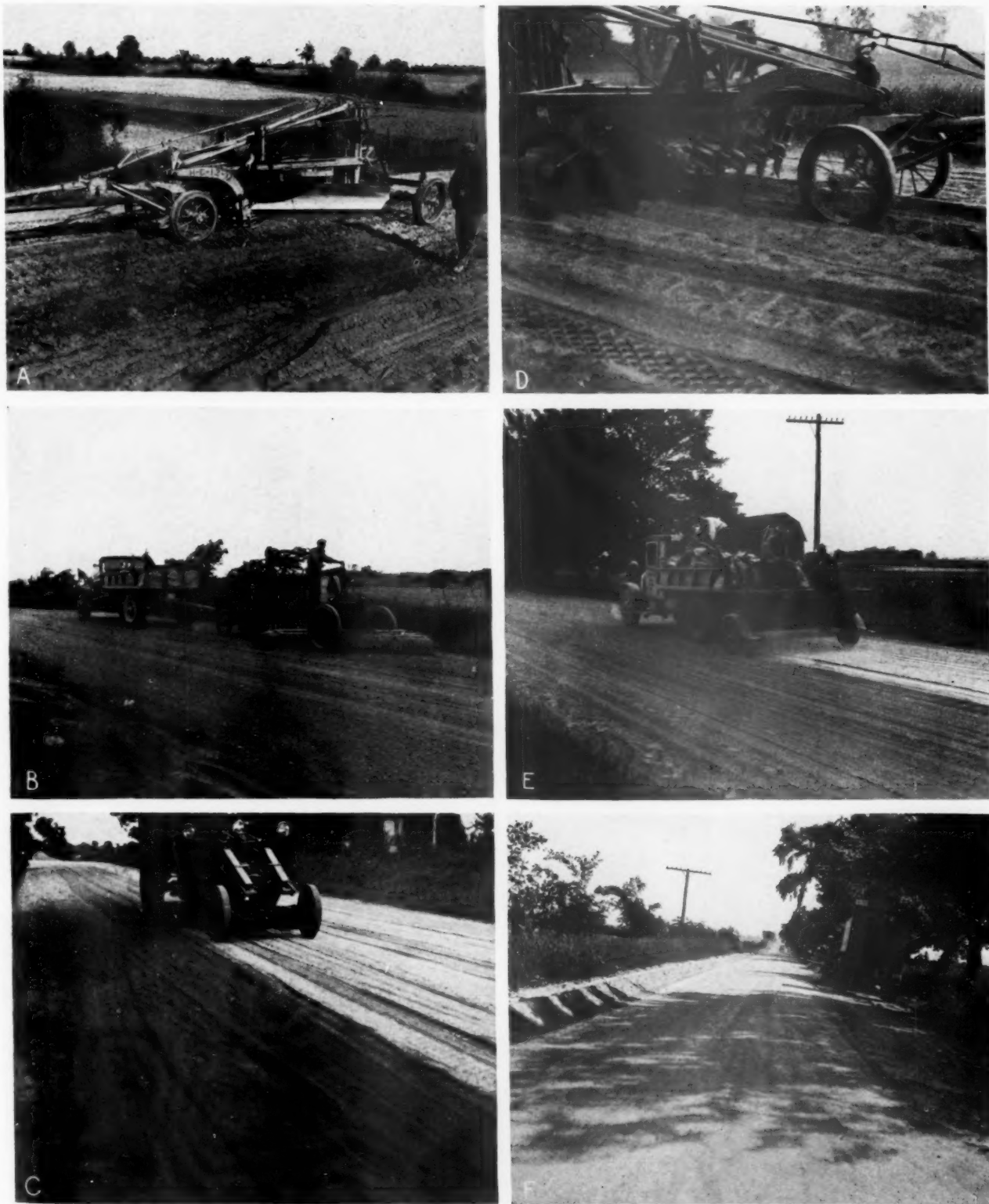


FIGURE 5.—STEPS IN SOIL ROAD CONSTRUCTION IN MICHIGAN. A, SCARIFYING OLD SURFACE; B, REMOVING LARGE STONE WITH RAKE; C, SPREADING PULVERIZED CLAY ADMIXTURE; D, DEEP BLADING TO MIX CLAY WITH OLD ROAD MATERIAL; E, SPREADING CHEMICAL OVER SMOOTHED SURFACE; F, MIXING BY BLADING IN WINDROWS.

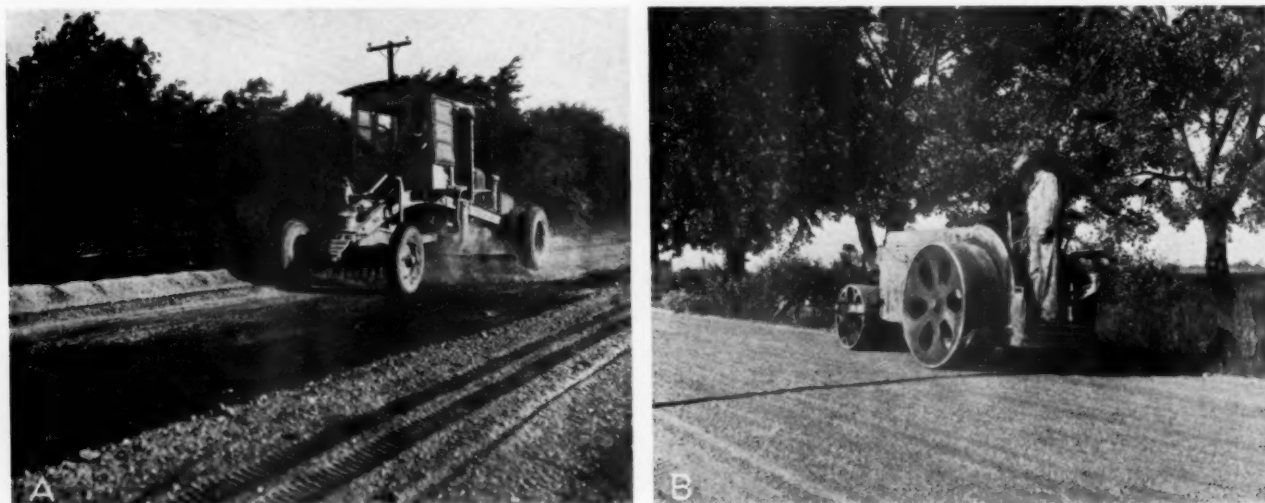


FIGURE 6.—A, SPREADING DRY MATERIAL OVER WETTED ROAD BED; B, ROLLING THE PARTIALLY DRY SURFACE.

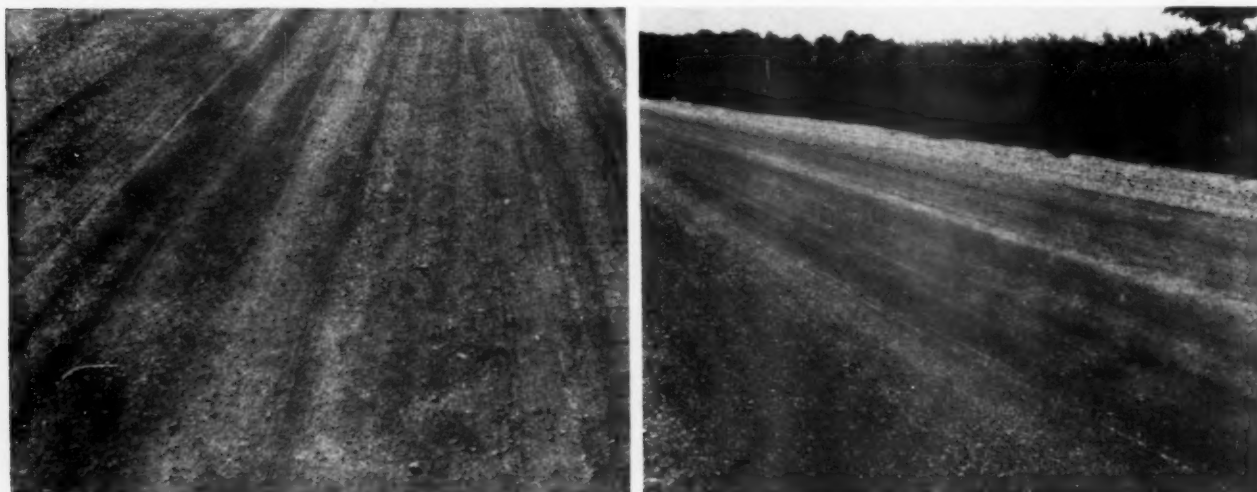


FIGURE 7.—SOIL SURFACES IN INDIANA CONTAINING DELIQUESCENT CHEMICALS.

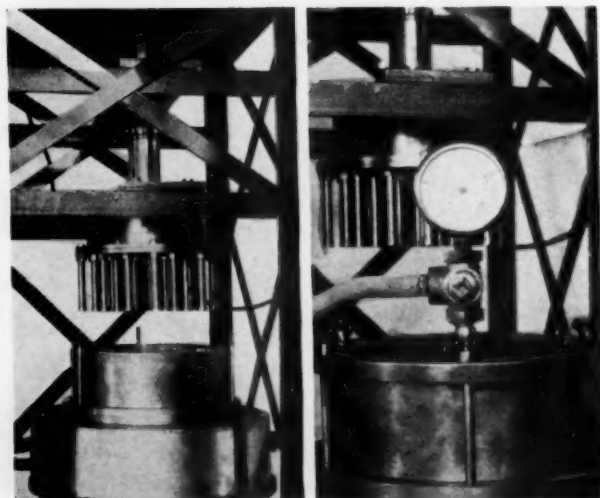


FIGURE 8.—APPARATUS FOR CONSOLIDATING SAMPLE AND TESTING FOR PERMEABILITY, CAPILLARITY, AND SHRINKAGE.

Figure 10 shows the two curves resulting from the test; the weight of dry soil-moisture content relation and the bearing value-moisture content relation. The weight of dry soil-moisture content curve discloses that for this soil a moisture content of about 19 percent is required if maximum compaction is to be attained. The corresponding bearing value is about 1,100 pounds per square inch.

If, at the specified compaction, the bearing value of this particular soil is indicated by the plasticity needle to be higher than 1,100 pounds, the increase can be considered as only temporary if the fill is to be unprotected from water after construction. Thus a bearing value of 1,600 pounds per square inch indicates a moisture content of slightly less than 17 percent. This corresponds to a dry weight of about 106 pounds per cubic foot. At this density the soil can take up moisture to a maximum of slightly more than 20 percent which, in turn corresponds to a bearing value of but 600 pounds per square inch.

Figure 11 illustrates how dry weight-moisture content curves may be used to disclose the effect of various admixtures in increasing or decreasing the stability of soil. It is shown that some admixtures serve to increase the optimum moisture content, others tend to



FIGURE 9.—COMPACTING SOIL IN PROCTOR CYLINDER AND DETERMINING CONSISTENCY OF FILL WITH PLASTICITY NEEDLE.

decrease it. As the optimum moisture content increases, the maximum density decreases.

By incorporating certain elements of the Proctor tests in a modified compression and permeability test, it seems possible to predetermine how well soils with admixtures, compacted according to current construction methods, will retain a high density under varying climatic and load conditions. The procedure is to compact the sample at optimum moisture content and then transfer it in the compacted state to the Terzaghi compression test apparatus and observe the compression and expansion characteristics.

The results of such tests are shown in figure 12, upper left. This curve is representative of one of the most troublesome of subgrade soils—due to shrinkage and plasticity—the highly colloidal, sticky, tenacious soil in zone B of the Fredell series. The curve shows that maximum density is reached at a moisture content equal to about 16 percent of the weight of the dry soil. At this moisture content a density indicated by a dry weight of 106 pounds per cubic foot is obtained. Results of compression and expansion tests on a sample of soil compacted at this moisture content are shown in the lower left of figure 12. The sample was placed in the apparatus, without having access to water, and a load applied in increments up to 8.2 tons per square foot. The load was then reduced to 0.05 ton per square foot. The results are shown by the broken lines.

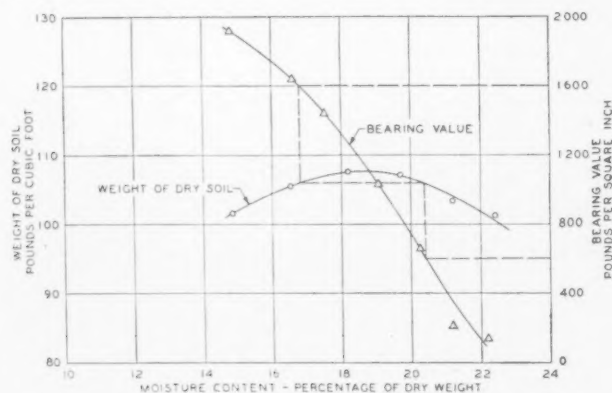


FIGURE 10.—DATA FURNISHED BY PROCTOR TESTS.

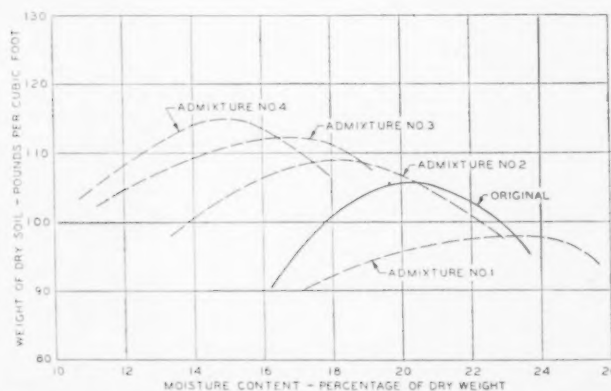


FIGURE 11.—EFFECT OF CHEMICAL ADMIXTURES IN REDUCING OPTIMUM MOISTURE CONTENT AND INCREASING THE DENSITY OF COMPACTED SAMPLES.

Water was then allowed to enter the testing apparatus and after a considerable interval of time the load was again increased to 8.2 tons per square foot and then reduced to 0.05 ton per square foot. These results are indicated by the full line which represents both load application and load removal.

Figure 12, C, D, and E shows results of similar tests on samples of the same soil in dust phase, at optimum moisture content but uncompacted, and on a sample wetted to about the liquid limit. In these curves volume change is indicated by the voids ratio. The small change in volume of the compacted sample resulting from wetting and change in load, as compared with that of the same soil in the other states, is striking. This is further emphasized by figure 13 which shows the same test results in terms of thickness of soil layer per unit thickness of solids in the layer.

The results shown in figure 13 indicate that subgrades comprised of the highly plastic soils, such as the black waxy soils, the adobes and the gumbos, when manipulated at the proper moisture content, may be compacted to high densities which will remain fairly constant under widely changing conditions of load and access to water.

The consolidations shown were produced by load periods of 72 hours on samples about 1 centimeter thick. Expansions were measured after loads had been removed for periods of 24 to 48 hours. To produce an equal degree of consolidation in soil layers thicker than 1 centimeter, the duration of the load would vary as the square of the thickness of the layer.

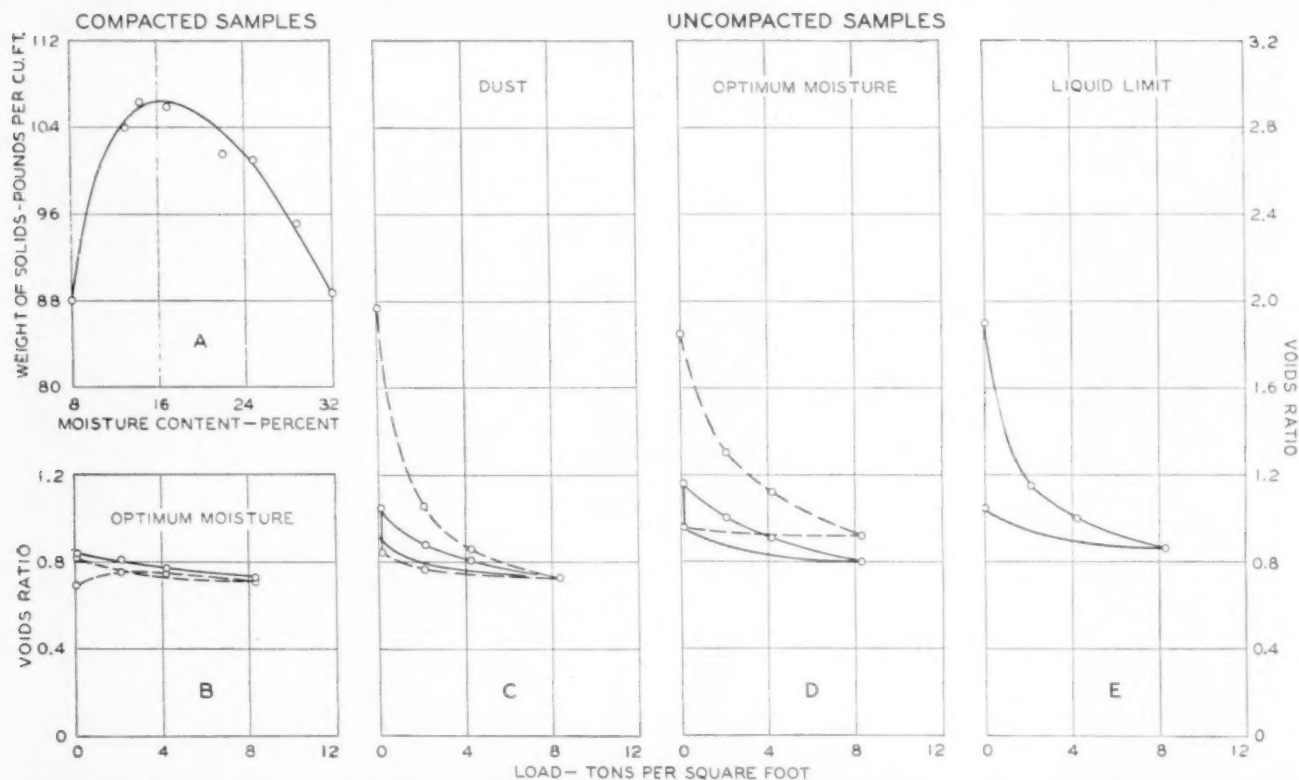


FIGURE 12.—RELATION BETWEEN MOISTURE CONTENT AND DENSITY AFTER COMPACTION OF IREDELL CLAY AND RESULTS OF COMPRESSION TESTS ON COMPACTIONED AND UNCOMPACTIONED SAMPLES.

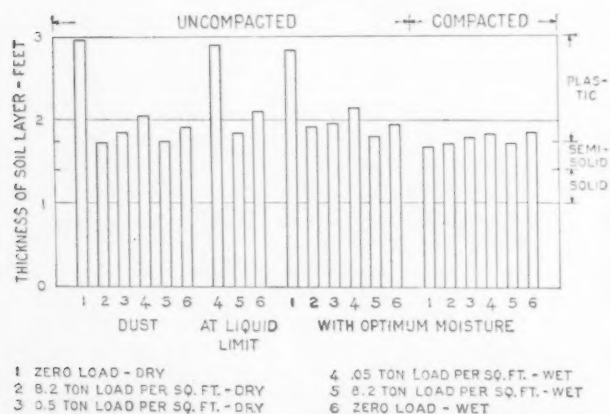


FIGURE 13.—THICKNESS OF A LAYER OF IREDELL CLAY CONTAINING THE EQUIVALENT OF 1 FOOT OF SOLIDS UNDER DIFFERENT TEST CONDITIONS. THE TERMS "WET" AND "DRY" REFER TO CONDITIONS SURROUNDING THE SAMPLE.

APPLICATION OF SURFACE CHEMISTRY TO SOIL STABILIZATION BEING STUDIED

The great possibilities in the application of surface chemistry to soil stabilization are indicated by the reports of Winterkorn,³⁴ Reagel and Schappler,³⁵ of the Missouri State Highway Department. Their work discloses that some bases have greater affinity for bitumen than for water and that the reverse is true for other bases. The use of soap as an electrolyzer facilitates the mixing of some soils with bituminous materials. The benefit of the soap treatment was

³⁴ Oiling Earth Roads, Application of Surface Chemistry, by Hans Winterkorn, Industrial and Engineering Chemistry, vol. 26, August 1934.

³⁵ Stabilizing Sand and Gravel Surfaces, by R. C. Schappler, Kansas Highway Conference, Manhattan, Kans., Feb. 5, 1934.

demonstrated in an experiment in which soap was used on one section of an earth-gravel-oil mixture and omitted on another section. A heavy rain washed the oil from the latter section but did not wash it from the soap-treated section. It is indicated that different soaps may be desirable for different soils. Ions from different bases may either increase or decrease shrinkage, plasticity and other properties on which stability depends. For every soil it is possible to select a cation for exchange which will adjust the properties of the soil as desired.

Among the substances suggested as having possible use as admixtures in soil densification are bituminous materials, portland cement, hydrated lime, calcium chloride, calcium silicate, calcium carbonate, soda ash, sodium silicate, and sodium chloride.

It is believed that the high densities of road surfaces treated with calcium chloride and salt are not due entirely to the deliquescence of these materials but are in part due to electrolytic effect in reducing the thickness of the moisture films. A limited number of compaction curves, such as shown in figure 11, support this conclusion.

It is possible that chemicals such as calcium chloride and common salt, which serve to lower the freezing temperature, might be beneficial in the colder climates in their effect on freezing.

STABILIZATION BY SURFACE TREATMENTS EFFECTIVE ONLY FOR SOILS OF GOOD QUALITY

The preceding discussion discloses methods of determining densities which can be produced by special methods and which can be maintained under a wide range in moisture and load conditions. The mainte-

nance of high density in a road surface, however, requires that subgrades and bases for thin wearing courses be constructed in such a manner as to prevent damage by water coming from beneath the surface and also that loss of moisture from the densified soil by evaporation be prevented. It is because of this requirement that a discussion of the benefits of waterproofing by surface treatment is included in this report.

Two conditions are essential if the waterproofing of a soil surface is to be worth while. The materials of the surface and base must be either impervious enough, or have sufficiently low capillarity to prevent the accumulation of enough capillary moisture to cause instability. The quality of materials necessary will be affected by climate, topography, and traffic. The surface treatment must be maintained sufficiently impervious to prevent the surface water entering clay soils from above and to prevent the evaporation of the cohesive moisture films from sandy soils.

Stabilization by surface treatment is excellently illustrated by the blotter-type tar and asphalt surface treatments on the heavy gumbo soil roads of western Minnesota and eastern North Dakota.³⁶ The top view of figure 14 shows a condition in the spring of a road west of Ada, Minn., prior to the first treatment in 1924. Gravel used for surfacing was found to have penetrated to depths as great as 3 feet. The lower view of figure 14 is a picture taken in the spring of the year and shows the condition of a similar road after receiving a surface treatment of bituminous material with gravel covering. On inspection in 1932, the total thickness of the surface treatment was found to be slightly less than 1 inch.

Bituminous surface treatments have long been used in the Southern States to change loose sandy and dusty materials into firm, stable, durable road surfaces. Prevention of evaporation accounts for at least part of this benefit.³⁷

LOW-COST ALL-WEATHER ROADS REQUIRED IN HIGHWAY PROGRAM

Only a small percentage of natural soils are of good quality for road surfacing. Even in Georgia, where soil conditions are particularly favorable, soils of the best quality are more the exception than the rule. Of 29 sand-clay Federal-aid projects reported by Dr. Strahan, but 3 had strong, hard surfaces, free from ruts, holes, or corrugations, indicative of class A material. Admixtures and chemical treatments are most often used to give low-grade materials those qualities naturally present in class A topsoils as a result of long cultivation and weathering and in well-graded gravels as a result of their composition. The admixtures and treatments have the additional advantage that they avoid the necessity of a dust-producing mulch surface.

Substantial progress has been made in the design of soil mixtures, and in the use of bituminous surface treatments and stabilization of the moisture content by means of treatment with deliquescent substances.

The tentative requirements for the design of stable mixtures given on page 277 are based upon extensive laboratory experiments, and observations of roads in service and represent a step toward the simplification of test procedure for identifying road soils for use in construction.

Selected soil surfaces are suitable for temporary surfacing on important roads. They can be placed im-



FIGURE 14.—A TYPICAL MINNESOTA GUMBO ROAD IN EARLY SPRING AND A ROAD ON SAME TYPE OF SOIL AFTER BEING TREATED WITH BITUMINOUS MATERIAL AND COVERED WITH A THIN LAYER OF GRAVEL.

mediately after the grading for use during the period of settlement and will give substantial support and increased life to pavements placed upon them.

The method of stabilization by densification at optimum moisture content has been utilized principally in connection with the construction of embankments for use as earth dams, although it is equally applicable for use in any kind of fill, subgrade or soil base-course construction.

Water attracted by the adsorptive affinity of soil particles for moisture cannot enter and soften the soil mass when the particles are covered with moisture films and the soil is compacted to maximum density at optimum moisture content. Under these conditions the tendency to expand and lose stability in the presence of moisture may be eliminated from highly plastic soils when protected by surface treatment. Densification will not be effective with soils in which the tendency to expand is due to elastic rebound such as those containing mica.

Field experimentation in the use of chemical admixtures which change the character of the soil include the use of portland cement, bituminous emulsions, and treatment with sodium silicate and calcium chloride in combination to produce calcium silicate precipitate.

Several sections of soil road stabilized with cement and given a bituminous surface treatment were constructed by the South Carolina State Highway Department during 1934. A bituminous emulsion was mixed with the soil in constructing an airport runway in Baltimore, Md. The use of the silicate-chloride method of treatment has been confined largely to the

³⁶ Blotter Treatment of Gravel Roads in the State of Minnesota, by F. C. Lang, Eighth Annual Asphalt Paving Conference, 1929.

³⁷ Tar Surface Treatment of Low Cost Roads, Public Roads, vol. 14, no. 1, March 1933.

stabilization of soil supporting buildings and other structures.

The stability furnished by compaction of soils at optimum moisture content suggests that vastly greater benefits may be expected when the interfacial colloidal films are stabilized by proper use of bitumen, portland cement, and the ions of sodium, potassium, and calcium.

New developments can be expected as progress is made in this vast and but little-explored field. The materials being investigated are low in cost and widely

different in character. They are subjected to varying weather conditions and traffic loads. The results obtained should be evaluated on the basis of the benefit rendered by the stabilizing procedure in comparison with its cost.

More than 2,000,000 miles of rural roads are unimproved. On much of this mileage surfacing is not economically justified, but there is a considerable mileage which should be surfaced and the extent to which this is done will depend on the cost.

PUBLICATION ON TREE WOUNDS

Questions concerning the proper treatment of wounds in roadside, shade, ornamental, street, and park trees are considered in Farmers' Bulletin No. 1726 of the United States Department of Agriculture. The publication is intended primarily for persons in charge of public or private property with little or no knowledge concerning the normal processes of a healthy tree or why and how wounds endanger the health of trees.

The simpler types of treatment for tree wounds, the bulletin explains, are within the range of almost any practical man who is familiar with the use of a saw, gouge, mallet, and paintbrush. Two axioms that should be borne in mind constantly are (1) that proper treatment of fresh-made wounds is the surest and best method of preventing disease or decay and needless

expense in the future, and (2) that all old wounds should be treated by some proper method. The practice of treating tree wounds is very old and, according to the bulletin, it is not a secret art, probably all of the best methods are well known.

The structure and life processes of trees are described and causes of injury discussed. What trees are worth treating, when the work may be done, and detailed methods are discussed. Numerous illustrations show the recommended methods of wound treatment.

Copies of this publication on tree wounds may be obtained free of charge from the Office of Information, United States Department of Agriculture, Washington, D. C., until the free supply is exhausted, or copies may be obtained for 5 cents from the Superintendent of Documents, Government Printing Office, Washington, D. C.

CURRENT STATUS OF UNITED STATES PUBLIC WORKS ROAD CONSTRUCTION

AS PROVIDED BY SECTION 204 OF THE NATIONAL INDUSTRIAL RECOVERY ACT (1934 FUNDS) AND BY THE ACT OF JUNE 18, 1934 (1935 FUNDS)

CLASS 1.—PROJECTS ON THE FEDERAL-AID HIGHWAY SYSTEM OUTSIDE OF MUNICIPALITIES

AS OF JANUARY 31, 1935

| STATE | APPORTIONMENTS | | COMPLETED | | | | UNDER CONSTRUCTION | | | | APPROVED FOR CONSTRUCTION | | | | BALANCE OF FUNDS AVAILABLE FOR NEW PROJECTS | | | |
|----------------|--|----------------------------------|------------|-------------------------|-------------------------|-----------|----------------------|-------------------------|-------------------------|-----------|---------------------------|-------------------------|-----------|-------------------------|---|-------------------------|-------------------------|--|
| | Sec. 204 of the Act of June 18, 1933 (1934 Fund) | Act of June 18, 1934 (1935 Fund) | Total Cost | 1934 Public Works Funds | 1935 Public Works Funds | Mileage | Estimated Total Cost | 1934 Public Works Funds | 1935 Public Works Funds | Mileage | 1934 Public Works Funds | 1935 Public Works Funds | Mileage | 1934 Public Works Funds | 1935 Public Works Funds | 1934 Public Works Funds | 1935 Public Works Funds | |
| Alabama | 3,947,793 | 2,129,921 | 6,077,714 | 2,129,921 | 2,129,921 | 2,129,921 | 2,129,921 | 2,129,921 | 2,129,921 | 2,129,921 | 2,129,921 | 2,129,921 | 2,129,921 | 2,129,921 | 2,129,921 | 2,129,921 | 2,129,921 | |
| Arizona | 3,478,575 | 3,134,712 | 6,613,287 | 3,134,712 | 3,134,712 | 3,134,712 | 3,134,712 | 3,134,712 | 3,134,712 | 3,134,712 | 3,134,712 | 3,134,712 | 3,134,712 | 3,134,712 | 3,134,712 | 3,134,712 | 3,134,712 | |
| Arkansas | 3,534,167 | 1,714,000 | 5,248,167 | 1,714,000 | 1,714,000 | 1,714,000 | 1,714,000 | 1,714,000 | 1,714,000 | 1,714,000 | 1,714,000 | 1,714,000 | 1,714,000 | 1,714,000 | 1,714,000 | 1,714,000 | 1,714,000 | |
| California | 7,912,928 | 3,713,643 | 11,626,571 | 3,713,643 | 3,713,643 | 3,713,643 | 3,713,643 | 3,713,643 | 3,713,643 | 3,713,643 | 3,713,643 | 3,713,643 | 3,713,643 | 3,713,643 | 3,713,643 | 3,713,643 | 3,713,643 | |
| Colorado | 3,437,265 | 2,424,504 | 5,861,769 | 2,424,504 | 2,424,504 | 2,424,504 | 2,424,504 | 2,424,504 | 2,424,504 | 2,424,504 | 2,424,504 | 2,424,504 | 2,424,504 | 2,424,504 | 2,424,504 | 2,424,504 | 2,424,504 | |
| Connecticut | 1,404,215 | 607,500 | 2,011,715 | 607,500 | 607,500 | 607,500 | 607,500 | 607,500 | 607,500 | 607,500 | 607,500 | 607,500 | 607,500 | 607,500 | 607,500 | 607,500 | 607,500 | |
| Delaware | 892,944 | 461,697 | 1,354,641 | 461,697 | 461,697 | 461,697 | 461,697 | 461,697 | 461,697 | 461,697 | 461,697 | 461,697 | 461,697 | 461,697 | 461,697 | 461,697 | 461,697 | |
| Florida | 2,035,353 | 1,115,600 | 3,150,953 | 1,115,600 | 1,115,600 | 1,115,600 | 1,115,600 | 1,115,600 | 1,115,600 | 1,115,600 | 1,115,600 | 1,115,600 | 1,115,600 | 1,115,600 | 1,115,600 | 1,115,600 | 1,115,600 | |
| Georgia | 5,095,592 | 2,592,745 | 7,688,337 | 2,592,745 | 2,592,745 | 2,592,745 | 2,592,745 | 2,592,745 | 2,592,745 | 2,592,745 | 2,592,745 | 2,592,745 | 2,592,745 | 2,592,745 | 2,592,745 | 2,592,745 | 2,592,745 | |
| Idaho | 2,166,858 | 1,131,910 | 3,298,768 | 1,131,910 | 1,131,910 | 1,131,910 | 1,131,910 | 1,131,910 | 1,131,910 | 1,131,910 | 1,131,910 | 1,131,910 | 1,131,910 | 1,131,910 | 1,131,910 | 1,131,910 | 1,131,910 | |
| Illinois | 4,442,467 | 3,060,041 | 7,502,508 | 3,060,041 | 3,060,041 | 3,060,041 | 3,060,041 | 3,060,041 | 3,060,041 | 3,060,041 | 3,060,041 | 3,060,041 | 3,060,041 | 3,060,041 | 3,060,041 | 3,060,041 | 3,060,041 | |
| Indiana | 5,018,931 | 2,643,478 | 7,662,409 | 2,643,478 | 2,643,478 | 2,643,478 | 2,643,478 | 2,643,478 | 2,643,478 | 2,643,478 | 2,643,478 | 2,643,478 | 2,643,478 | 2,643,478 | 2,643,478 | 2,643,478 | 2,643,478 | |
| Iowa | 5,037,820 | 2,217,261 | 7,255,081 | 2,217,261 | 2,217,261 | 2,217,261 | 2,217,261 | 2,217,261 | 2,217,261 | 2,217,261 | 2,217,261 | 2,217,261 | 2,217,261 | 2,217,261 | 2,217,261 | 2,217,261 | 2,217,261 | |
| Kansas | 5,004,802 | 2,594,437 | 7,599,239 | 2,594,437 | 2,594,437 | 2,594,437 | 2,594,437 | 2,594,437 | 2,594,437 | 2,594,437 | 2,594,437 | 2,594,437 | 2,594,437 | 2,594,437 | 2,594,437 | 2,594,437 | 2,594,437 | |
| Kentucky | 3,751,605 | 1,527,354 | 5,278,959 | 1,527,354 | 1,527,354 | 1,527,354 | 1,527,354 | 1,527,354 | 1,527,354 | 1,527,354 | 1,527,354 | 1,527,354 | 1,527,354 | 1,527,354 | 1,527,354 | 1,527,354 | 1,527,354 | |
| Louisiana | 2,711,152 | 1,380,419 | 4,091,571 | 1,380,419 | 1,380,419 | 1,380,419 | 1,380,419 | 1,380,419 | 1,380,419 | 1,380,419 | 1,380,419 | 1,380,419 | 1,380,419 | 1,380,419 | 1,380,419 | 1,380,419 | 1,380,419 | |
| Maine | 1,617,960 | 793,644 | 2,411,604 | 793,644 | 793,644 | 793,644 | 793,644 | 793,644 | 793,644 | 793,644 | 793,644 | 793,644 | 793,644 | 793,644 | 793,644 | 793,644 | 793,644 | |
| Maryland | 1,787,285 | 885,078 | 2,672,363 | 885,078 | 885,078 | 885,078 | 885,078 | 885,078 | 885,078 | 885,078 | 885,078 | 885,078 | 885,078 | 885,078 | 885,078 | 885,078 | 885,078 | |
| Massachusetts | 1,101,716 | 1,632,474 | 2,734,190 | 1,632,474 | 1,632,474 | 1,632,474 | 1,632,474 | 1,632,474 | 1,632,474 | 1,632,474 | 1,632,474 | 1,632,474 | 1,632,474 | 1,632,474 | 1,632,474 | 1,632,474 | 1,632,474 | |
| Michigan | 6,091,532 | 3,226,284 | 9,317,816 | 3,226,284 | 3,226,284 | 3,226,284 | 3,226,284 | 3,226,284 | 3,226,284 | 3,226,284 | 3,226,284 | 3,226,284 | 3,226,284 | 3,226,284 | 3,226,284 | 3,226,284 | 3,226,284 | |
| Minnesota | 4,561,011 | 2,642,244 | 7,203,255 | 2,642,244 | 2,642,244 | 2,642,244 | 2,642,244 | 2,642,244 | 2,642,244 | 2,642,244 | 2,642,244 | 2,642,244 | 2,642,244 | 2,642,244 | 2,642,244 | 2,642,244 | 2,642,244 | |
| Mississippi | 3,449,337 | 2,201,148 | 5,650,485 | 2,201,148 | 2,201,148 | 2,201,148 | 2,201,148 | 2,201,148 | 2,201,148 | 2,201,148 | 2,201,148 | 2,201,148 | 2,201,148 | 2,201,148 | 2,201,148 | 2,201,148 | 2,201,148 | |
| Missouri | 3,737,532 | 2,132,426 | 5,869,958 | 2,132,426 | 2,132,426 | 2,132,426 | 2,132,426 | 2,132,426 | 2,132,426 | 2,132,426 | 2,132,426 | 2,132,426 | 2,132,426 | 2,132,426 | 2,132,426 | 2,132,426 | 2,132,426 | |
| Montana | 4,465,469 | 2,714,208 | 7,179,677 | 2,714,208 | 2,714,208 | 2,714,208 | 2,714,208 | 2,714,208 | 2,714,208 | 2,714,208 | 2,714,208 | 2,714,208 | 2,714,208 | 2,714,208 | 2,714,208 | 2,714,208 | 2,714,208 | |
| Nebraska | 3,914,441 | 1,942,182 | 5,856,623 | 1,942,182 | 1,942,182 | 1,942,182 | 1,942,182 | 1,942,182 | 1,942,182 | 1,942,182 | 1,942,182 | 1,942,182 | 1,942,182 | 1,942,182 | 1,942,182 | 1,942,182 | 1,942,182 | |
| Nevada | 2,909,347 | 1,350,356 | 4,259,703 | 1,350,356 | 1,350,356 | 1,350,356 | 1,350,356 | 1,350,356 | 1,350,356 | 1,350,356 | 1,350,356 | 1,350,356 | 1,350,356 | 1,350,356 | 1,350,356 | 1,350,356 | 1,350,356 | |
| New Hampshire | 795,759 | 484,731 | 1,280,490 | 484,731 | 484,731 | 484,731 | 484,731 | 484,731 | 484,731 | 484,731 | 484,731 | 484,731 | 484,731 | 484,731 | 484,731 | 484,731 | 484,731 | |
| New Jersey | 3,173,019 | 951,379 | 4,124,398 | 951,379 | 951,379 | 951,379 | 951,379 | 951,379 | 951,379 | 951,379 | 951,379 | 951,379 | 951,379 | 951,379 | 951,379 | 951,379 | 951,379 | |
| New Mexico | 2,446,644 | 1,676,769 | 4,123,413 | 1,676,769 | 1,676,769 | 1,676,769 | 1,676,769 | 1,676,769 | 1,676,769 | 1,676,769 | 1,676,769 | 1,676,769 | 1,676,769 | 1,676,769 | 1,676,769 | 1,676,769 | 1,676,769 | |
| New York | 10,465,672 | 5,521,490 | 15,987,162 | 5,521,490 | 5,521,490 | 5,521,490 | 5,521,490 | 5,521,490 | 5,521,490 | 5,521,490 | 5,521,490 | 5,521,490 | 5,521,490 | 5,521,490 | 5,521,490 | 5,521,490 | 5,521,490 | |
| North Carolina | 4,761,147 | 2,040,068 | 6,801,215 | 2,040,068 | 2,040,068 | 2,040,068 | 2,040,068 | 2,040,068 | 2,040,068 | 2,040,068 | 2,040,068 | 2,040,068 | 2,040,068 | 2,040,068 | 2,040,068 | 2,040,068 | 2,040,068 | |
| North Dakota | 2,902,224 | 1,469,444 | 4,371,668 | 1,469,444 | 1,469,444 | 1,469,444 | 1,469,444 | 1,469,444 | 1,469,444 | 1,469,444 | 1,469,444 | 1,469,444 | 1,469,444 | 1,469,444 | 1,469,444 | 1,469,444 | 1,469,444 | |
| Ohio | 7,277,754 | 5,539,596 | 12,817,350 | 5,539,596 | 5,539,596 | 5,539,596 | 5,539,596 | 5,539,596 | 5,539,596 | 5,539,596 | 5,539,596 | 5,539,596 | 5,539,596 | 5,539,596 | 5,539,596 | 5,539,596 | 5,539,596 | |
| Oklahoma | 4,604,399 | 2,342,520 | 6,946,919 | 2,342,520 | 2,342,520 | 2,342,520 | 2,342,520 | 2,342,520 | 2,342,520 | 2,342,520 | 2,342,520 | 2,342,520 | 2,342,520 | 2,342,520 | 2,342,520 | 2,342,520 | 2,342,520 | |
| Oregon | 3,093,444 | 1,462,741 | 4,556,185 | 1,462,741 | 1,462,741 | 1,462,741 | 1,462,741 | 1,462,741 | 1,462,741 | 1,462,741 | 1,462,741 | 1,462,741 | 1,462,741 | 1,462,741 | 1,462,741 | 1,462,741 | 1,462,741 | |
| Pennsylvania | 6,691,194 | 4,554,082 | 11,245,276 | 4,554,082 | 4,554,082 | 4,554,082 | 4,554,082 | 4,554,082 | 4,554,082 | 4,554,082 | 4,554,082 | 4,554,082 | 4,554,082 | 4,554,082 | 4,554,082 | 4,554,082 | 4,554,082 | |
| Rhode Island | 979,367 | 464,572 | 1,443,939 | 464,572 | 464,572 | 464,572 | 464,572 | 464,572 | 464,572 | 464,572 | 464,572 | 464,572 | 464,572 | 464,572 | 464,572 | 464,572 | 464,572 | |
| South Carolina | 2,793,945 | 1,385,477 | 4,179,422 | 1,385,477 | 1,385,477 | 1,385,477 | 1,385,477 | 1,385,477 | 1,385,477 | 1,385,477 | 1,385,477 | 1,385,477 | 1,385,477 | 1,385,477 | 1,385,477 | 1,385,477 | 1,385,477 | |
| South Dakota | 5,095,735 | 1,551,441 | 6,647,176 | 1,551,441 | 1,551,441 | 1,551,441 | 1,551,441 | 1,551,441 | 1,551,441 | 1,551,441 | 1,551,441 | 1,551,441 | 1,551,441 | 1,551,441 | 1,551,441 | 1,551,441 | 1,551,441 | |
| Tennessee | 4,446,309 | 2,109,453 | 6,555,762 | 2,109,453 | 2,109,453 | 2,109,453 | 2,109,453 | 2,109,453 | 2,109,453 | 2,109,453 | 2,109,453 | 2,109,453 | 2,109,453 | 2,109,453 | 2,109,453 | 2,109,453 | 2,109,453 | |
| Texas | 11,548,645 | 6,854,253 | 18,402,898 | 6,854,253 | 6,854,253 | 6,854,253 | 6,854,253 | 6,854,253 | 6,854,253 | 6,854,253 | 6,854,253 | 6,854,253 | 6,854,253 | 6,854,253 | 6,854,253 | 6,854,253 | 6,854,253 | |
| Utah | 2,367,209 | 1,066,346 | 3,433,555 | 1,066,346 | 1,066,346 | 1,066,346 | 1,066,346 | 1,066,346 | 1,066,346 | 1,066,346 | 1,066,346 | 1,066,346 | 1,066,346 | 1,066,346 | 1,066,346 | 1,066,346 | 1,066,346 | |
| Vermont | 924,184 | 466,042 | 1,390,226 | 466,042 | 466,042 | 466,042 | 466,042 | 466,042 | 466,042 | 466,042 | 466,042 | 466,042 | 466,042 | 466,042 | 466,042 | 466,042 | 466,042 | |
| Virginia | 3,708,379 | 1,882,693 | 5,591,072 | 1,882,693 | 1,882,693 | 1,882,693 | 1,882,693 | 1,882,693 | 1,882,693 | 1,882,693 | 1,882,693 | 1,882,693 | 1,882,693 | 1,882,693 | 1,882,693 | 1,882,693 | 1,882,693 | |
| Washington | 3,091,934 | 1,551,206 | | | | | | | | | | | | | | | | |

CURRENT STATUS OF UNITED STATES PUBLIC WORKS ROAD CONSTRUCTION

AS PROVIDED BY SECTION 204 OF THE NATIONAL INDUSTRIAL RECOVERY ACT (1934 FUNDS) AND BY THE ACT OF JUNE 18, 1934 (1935 FUNDS)

CLASS 2.—PROJECTS ON EXTENSIONS OF THE FEDERAL-AID HIGHWAY SYSTEM INTO AND THROUGH MUNICIPALITIES

AS OF JANUARY 31, 1935

| STATE | APPORTIONMENTS | | | COMPLETED | | | UNDER CONSTRUCTION | | | | APPROVED FOR CONSTRUCTION | | | BALANCE OF FUNDS AVAILABLE FOR NEW PROJECTS | |
|----------------------|--|----------------------------------|-------------|-------------------------|-------------------------|---------|----------------------|-------------------------|-------------------------|---------|---------------------------|-------------------------|---------|---|-------------------------|
| | Sec. 204 of the Act of June 18, 1934 (1934 Fund) | Act of June 18, 1934 (1934 Fund) | Total Cost | 1934 Public Works Funds | 1935 Public Works Funds | Mileage | Estimated Total Cost | 1934 Public Works Funds | 1935 Public Works Funds | Mileage | 1934 Public Works Funds | 1935 Public Works Funds | Mileage | 1934 Public Works Funds | 1935 Public Works Funds |
| Alabama | 2,359,928 | 1,059,564 | 3,419,492 | 1,094,208 | 6,592 | 30.6 | 1,212,893 | 1,139,090 | 73,193 | 35.2 | 149,322 | 66,884 | 1.9 | 166,610 | 925,922 |
| Arizona | 807,982 | 357,191 | 1,165,173 | 616,235 | | 12.3 | 80,819 | 555,531 | 15,124 | 5.5 | 101,016 | 117,794 | 1.1 | 21,946 | 267,542 |
| Arkansas | 1,584,534 | 637,075 | 2,221,609 | 1,880,582 | | 35.5 | 959,194 | 789,009 | 301,900 | 10.3 | | 320,632 | 4.6 | 27,045 | 739,271 |
| California | 4,213,946 | 2,219,360 | 6,433,306 | 3,402,117 | 13,406 | 46.7 | 1,312,464 | 789,009 | 5,716 | 1.2 | | 370,678 | 6.8 | 22,899 | 1,596,428 |
| Colorado | 1,718,633 | 190,000 | 1,908,633 | 1,704,869 | | 35.9 | 5,716 | 194,632 | 144,632 | | | | 2.0 | 13,764 | 406,044 |
| Connecticut | 802,407 | 486,900 | 1,289,307 | 802,199 | | 10.2 | 194,632 | | | | | | | 1.2 | 1,125,452 |
| Delaware | 1,177,680 | 230,489 | 1,408,169 | 1,177,680 | | 7.4 | 1,177,680 | 399,716 | 94,180 | 7.7 | 4,323 | 28,263 | 7 | 7,313 | 176,669 |
| District of Columbia | 1,410,000 | 501,200 | 1,911,200 | 1,410,000 | | 17.4 | 1,410,000 | 399,716 | 7,400 | 14.4 | 286,820 | 146,880 | 10.7 | 210,684 | 406,044 |
| Florida | 2,184,000 | 1,178,373 | 3,362,373 | 1,333,015 | | 37.8 | 897,791 | 894,100 | 3,641 | | | | | 1,125,452 | 281,867 |
| Idaho | 1,197,429 | 324,186 | 1,521,615 | 1,121,373 | 2,643 | 19.4 | 67,694 | 45,372 | 22,282 | 9.4 | 57,163 | 2,156 | 1.1 | 31,044 | 294,045 |
| Illinois | 7,476,075 | 2,515,461 | 9,991,536 | 5,730,675 | 62.9 | 62.9 | 1,777,674 | 1,681,534 | 96,336 | 10.1 | 216,396 | 835,201 | 6.5 | 28,963 | 1,602,184 |
| Indiana | 4,287,090 | 2,035,995 | 6,323,085 | 2,857,775 | | 61.3 | 1,216,466 | 1,216,466 | | | | | | | 825,693 |
| Iowa | 2,614,472 | 1,311,000 | 3,925,472 | 1,935,664 | 6,695 | 53.3 | 727,104 | 659,108 | 51,367 | 9.2 | 146,000 | 235,285 | 10.3 | 5,695 | 624,463 |
| Kansas | 1,171,412 | 1,171,412 | 2,342,824 | 2,085,677 | 2,445 | 30.8 | 871,787 | 410,998 | 315,526 | 5.7 | 94,506 | 280,182 | 5.9 | | |
| Kentucky | 1,927,428 | 579,578 | 2,507,006 | 1,332,461 | | | 993,028 | 495,167 | 89,533 | | | | | | |
| Louisiana | 1,716,577 | 794,560 | 2,511,137 | 670,442 | | 17.6 | 902,694 | 853,474 | 20,000 | 10.3 | 181,597 | 317,818 | 9.5 | 13,684 | 146,742 |
| Maine | 909,478 | 490,045 | 1,399,523 | 821,221 | 34,665 | 16.4 | 34,665 | 34,665 | | | | | | 50,495 | 278,906 |
| Maryland | 492,515 | 492,515 | 985,030 | 384,134 | | 4.1 | 911,699 | 384,134 | | | 94,834 | 111,539 | 2.8 | 394,031 | 552,515 |
| Massachusetts | 5,007,199 | 487,600 | 5,494,799 | 1,673,562 | | 12.3 | 3,073,328 | 2,996,104 | 52,244 | 5.4 | | 196,434 | 1.3 | 137,533 | 598,913 |
| Michigan | 1,613,142 | 3,194,195 | 4,807,337 | 3,070,406 | 101,920 | 39.0 | 1,326,500 | 412,750 | 931,250 | 6.8 | 14,950 | 370,850 | 9.8 | 2,131 | 209,092 |
| Minnesota | 1,421,494 | 3,719,145 | 5,140,639 | 3,018,187 | 194,608 | 108.5 | 358,934 | 155,856 | 204,662 | 4.7 | | 32,618 | 4.7 | 945,100 | 989,366 |
| Mississippi | 1,794,669 | 845,096 | 2,639,765 | 804,434 | | 20.0 | 716,135 | 653,171 | 63,024 | 23.6 | 314,314 | 69,289 | 8.9 | 224,407 | 752,793 |
| Missouri | 1,617,412 | 1,617,412 | 3,234,824 | 2,094,266 | | 32.4 | 1,981,693 | 1,034,510 | 101,345 | 12.4 | 53,477 | 86,105 | 2.3 | 76,844 | 1,430,001 |
| Montana | 1,135,362 | 113,092 | 1,248,454 | 1,056,676 | | | 65,264 | 34,716 | 5,994 | 4.5 | 8,796 | 33,250 | 3.2 | 15,574 | 73,666 |
| Nebraska | 1,927,840 | 991,091 | 2,918,931 | 1,933,553 | 104,535 | 35.7 | 287,684 | 16,107 | 287,684 | 3.5 | | 508,365 | 10.5 | 3,687 | 150,508 |
| Nevada | 500,051 | 100,000 | 600,051 | 502,397 | | 8.8 | 65,458 | 65,458 | | | | | | 37,464 | 49,666 |
| New Hampshire | 706,640 | 282,366 | 989,006 | 664,778 | 94,094 | 15.9 | 131,423 | | 131,613 | 3.0 | | 1,000 | | | 56,699 |
| New Jersey | 3,417,921 | 1,409,560 | 4,827,481 | 2,361,467 | | 30.0 | 1,293,091 | 813,946 | 334,714 | 6.6 | | 69,432 | 1.7 | 19,695 | 1,393,716 |
| New Mexico | 1,379,467 | 1,379,467 | 2,758,934 | 1,379,467 | | 31.3 | 1,379,467 | 1,379,467 | 180,097 | 8.9 | | 180,097 | 1.7 | 101,524 | 279,377 |
| New York | 8,259,661 | 3,940,621 | 12,200,282 | 6,247,552 | 5,890,351 | 53.2 | 4,170,403 | 2,296,556 | 1,704,900 | 23.5 | | 782,000 | 5.6 | 64,753 | 1,449,721 |
| North Carolina | 2,380,573 | 1,210,256 | 3,590,829 | 1,949,471 | 26,737 | 73.3 | 347,120 | 270,214 | 33,334 | 8.5 | 161,347 | 199,017 | 6.5 | 28,022 | 931,084 |
| North Dakota | 1,491,112 | 739,749 | 2,230,861 | 1,024,706 | | 43.4 | 1,97,078 | 121,848 | 75,250 | 7.2 | 271,222 | 50,732 | 20.3 | 27,356 | 544,760 |
| Ohio | 2,359,593 | 4,561,459 | 6,921,052 | 4,561,459 | 15,808 | 97.8 | 846,280 | 226,500 | 219,760 | 5.3 | | 1,015,240 | 13.9 | 62,075 | 1,105,464 |
| Oklahoma | 2,398,200 | 1,171,287 | 3,569,487 | 1,733,096 | | 34.3 | 635,412 | 535,691 | 95,796 | 9.7 | 1,326 | 294,407 | 3.2 | 43,194 | 780,732 |
| Oregon | 1,405,748 | 667,977 | 2,073,725 | 1,405,748 | | 27.8 | 112,979 | 112,979 | 112,979 | 1.6 | | 47,611 | 7.3 | 6,594 | 537,309 |
| Pennsylvania | 4,694,948 | 2,397,703 | 7,092,651 | 3,846,347 | 66,031 | 94.7 | 1,634,690 | 1,512,490 | 244,527 | 15.8 | 32,000 | 1,467,065 | 15.0 | 62,151 | 630,079 |
| Rhode Island | 579,625 | 295,000 | 874,625 | 527,914 | | 7.4 | 36,001 | 36,001 | 36,001 | 6 | | 42,750 | 17,957 | 52,609 | 214,939 |
| South Carolina | 1,364,791 | 682,714 | 2,047,505 | 1,364,791 | | 35.0 | 111,931 | 111,931 | 4,169 | 14.6 | 82,065 | 37,522 | 6.4 | 37,049 | 614,939 |
| South Dakota | 1,364,791 | 682,714 | 2,047,505 | 1,364,791 | | 35.0 | 111,931 | 111,931 | 4,169 | 14.6 | 82,065 | 37,522 | 6.4 | 37,049 | 614,939 |
| Tennessee | 2,123,195 | 1,121,790 | 3,244,985 | 1,942,496 | | 22.8 | 580,587 | 475,617 | 104,570 | 9.2 | 294,300 | 194,196 | 10.9 | 111,030 | 1,677,642 |
| Texas | 6,462,465 | 1,795,000 | 8,257,465 | 4,107,900 | 65,900 | 104.1 | 2,441,789 | 2,441,789 | 3,122 | 17.3 | 5,130 | 295,000 | 6.3 | 209 | 151,273 |
| Utah | 778,626 | 533,173 | 1,311,799 | 744,473 | | 20.2 | 806,999 | 184,000 | 71,000 | 2.3 | | | | | |
| Vermont | 900,609 | 240,611 | 1,141,220 | 900,609 | | 12.9 | 112,873 | 58,838 | 87,000 | 2.4 | 32,213 | 164,440 | 1.1 | 280,585 | 115,611 |
| Virginia | 2,004,462 | 1,977,265 | 3,981,727 | 1,977,265 | | 32.4 | 215,895 | 189,333 | 215,895 | 5.9 | 36,438 | 244,141 | 6.9 | 4,474 | 316,567 |
| Washington | 1,977,265 | 1,977,265 | 3,954,530 | 1,977,265 | | 32.4 | 215,895 | 189,333 | 215,895 | 5.9 | 36,438 | 244,141 | 6.9 | 4,474 | 316,567 |
| West Virginia | 1,377,265 | 1,377,265 | 2,754,530 | 1,377,265 | | 32.4 | 215,895 | 189,333 | 215,895 | 5.9 | 36,438 | 244,141 | 6.9 | 4,474 | 316,567 |
| Wisconsin | 1,377,265 | 1,377,265 | 2,754,530 | 1,377,265 | | 32.4 | 215,895 | 189,333 | 215,895 | 5.9 | 36,438 | 244,141 | 6.9 | 4,474 | 316,567 |
| Wyoming | 1,377,265 | 1,377,265 | 2,754,530 | 1,377,265 | | 32.4 | 215,895 | 189,333 | 215,895 | 5.9 | 36,438 | 244,141 | 6.9 | 4,474 | 316,567 |
| District of Columbia | 364,235 | 283,460 | 647,695 | 364,235 | | 6.5 | 250,164 | 250,164 | | | | | | 13,766 | 14,381 |
| Hawaii | | | | | | | | | | | | | | | |
| TOTALS | 115,737,423 | 49,278,597 | 165,016,020 | 87,299,069 | 954,248 | 1,666.2 | 35,378,978 | 26,126,793 | 7,004,013 | 363.2 | 2,776,426 | 10,744,717 | 234.8 | 3,317,769 | 30,567,569 |

CURRENT STATUS OF UNITED STATES PUBLIC WORKS ROAD CONSTRUCTION

AS PROVIDED BY SECTION 204 OF THE NATIONAL INDUSTRIAL RECOVERY ACT (1934 FUNDS) AND BY THE ACT OF JUNE 18, 1934 (1935 FUNDS)

CLASS 3.—PROJECTS ON SECONDARY OR FEEDER ROADS

AS OF JANUARY 31, 1935

| STATE | Sec. 204 of the Act (1934 Fund) | Act of June 18, 1934 (1935 Fund) | APPROPRIATIONS | | | COMPLETED | | | UNDER CONSTRUCTION | | | APPROVED FOR CONSTRUCTION | | | BALANCE OF FUNDS AVAILABLE FOR NEW PROJECTS | | |
|----------------------|------------------------------------|-------------------------------------|----------------|-------------------------------|-------------------------------|-----------|-------------------------|-------------------------------|-------------------------------|---------|-------------------------------|-------------------------------|---------|-------------------------------|--|-------------------------------|-------------------------------|
| | | | Total Cost | 1934 Public Works Funds | 1935 Public Works Funds | Mileage | Estimated Total Cost | 1934 Public Works Funds | 1935 Public Works Funds | Mileage | 1934 Public Works Funds | 1935 Public Works Funds | Mileage | 1934 Public Works Funds | 1935 Public Works Funds | 1934 Public Works Funds | 1935 Public Works Funds |
| Alabama | 2,032,462 | 1,004,960 | \$ 697,450 | \$ 697,450 | | 46.0 | \$ 1,442,743 | \$ 1,000,000 | \$ 442,743 | 109.3 | \$ 5,475 | \$ 346,192 | 22.1 | \$ 34,593 | \$ 574,055 | | |
| Arizona | 525,453 | 998,032 | 550,237 | 511,610 | | 42.5 | 306,633 | 7,813 | 260,093 | 21.5 | | 102,464 | 6.7 | 73,334 | 656,401 | | |
| Arkansas | 1,449,634 | 657,004 | 959,387 | 957,201 | | 124.6 | 516,293 | 447,626 | 447,626 | 40.4 | | 102,464 | 28.2 | | 684,358 | | |
| California | 3,440,440 | 1,999,203 | 3,346,627 | 2,661,768 | | 161.2 | 1,110,698 | 938,086 | 361,800 | 28.4 | | 42,530 | 12.9 | 686 | 1,212,487 | | |
| Colorado | 1,718,632 | 871,602 | 1,721,358 | 1,684,132 | | 170.7 | 847,796 | 699,120 | 222,850 | 19.0 | | 11,129 | 3.4 | | 346,162 | | |
| Connecticut | 659,150 | 420,868 | | | | | | | | | | | | | 186,859 | | |
| Delaware | 448,864 | 230,849 | 289,891 | 216,551 | | 24.1 | 390,690 | 228,623 | 127,893 | 35.6 | | 73,559 | 1.9 | 1,690 | 39,665 | | |
| Florida | 1,502,815 | 1,045,943 | 1,280,232 | 1,274,166 | | 77.5 | 356,943 | 93,310 | 358,943 | 21.0 | | 183,703 | 10.8 | 28,630 | 611,041 | | |
| Georgia | 2,350,973 | 1,276,375 | 1,159,287 | 1,158,044 | | 81.2 | 935,462 | 93,310 | 9,152 | 72.2 | 79,928 | | | 199,691 | 1,005,519 | | |
| I Idaho | 1,121,262 | 424,940 | 1,307,631 | 1,118,961 | | 186.5 | 382,718 | 377,447 | 919,027 | 42.5 | | 51,700 | 6.4 | 2,601 | 334,854 | | |
| Illinois | 5,652,228 | 3,346,155 | 1,301,589 | 1,488,634 | | 119.0 | 4,367,487 | 3,684,860 | 919,027 | 294.6 | 93,933 | 2,284,358 | 102.7 | 14,821 | 138,140 | | |
| Indiana | 731,872 | 209,900 | 604,572 | 604,572 | | 44.2 | 272,102 | 272,102 | | 40.7 | 46,460 | 16,356 | 3.5 | 6,749 | 153,944 | | |
| Iowa | 2,413,358 | 1,590,000 | 2,004,021 | 1,932,895 | | 295.1 | 1,159,334 | 404,850 | 550,100 | 192.2 | | 724,190 | 167.7 | 55,613 | 248,300 | | |
| Kansas | 2,522,102 | 1,279,419 | 1,940,421 | 1,776,032 | | 202.0 | 1,172,892 | 637,717 | 534,573 | 74.8 | 8,692 | 279,000 | 42.2 | 6,045 | 434,767 | | |
| Kentucky | 1,437,926 | 1,336,409 | 1,822,617 | 1,774,078 | | 210.0 | 712,944 | 65,833 | 686,379 | 74.5 | 21,549 | 279,000 | 51.1 | | | | |
| Louisiana | 1,398,862 | 838,953 | 950,765 | 949,942 | | 46.1 | 326,143 | 323,941 | 296,412 | 14.3 | 123,793 | 334,474 | 24.5 | 1,165 | 504,479 | | |
| Maine | 642,479 | 427,697 | 1,060,215 | 835,952 | | 90.4 | 282,470 | 5,000 | 296,412 | 21.4 | | 16,526 | 7.7 | 1,527 | 8,404 | | |
| Maryland | 891,152 | 1,067,934 | 661,949 | 640,959 | | | 447,351 | 284,250 | 253,101 | 25.5 | 20,439 | 413,720 | 12.1 | 5,534 | 431,113 | | |
| Massachusetts | 448,185 | 870,000 | 1,669,791 | 1,669,791 | | 15.2 | 1,032,877 | 181,727 | 676,250 | 41.1 | | 49,403 | 2.0 | 18,444 | 820,497 | | |
| Michigan | 3,104,097 | 1,613,142 | 2,867,212 | 2,817,566 | | 205.6 | 769,631 | 341,133 | 503,694 | 94.5 | | 447,460 | 27.6 | 17,146 | 315,279 | | |
| Minnesota | 2,376,415 | 1,361,813 | 2,314,276 | 2,216,135 | | 63.116 | 205,6 | | | | | 479,720 | 50.3 | | | | |
| Mississippi | 1,744,669 | 354,023 | 693,348 | 693,348 | | 66.2 | 767,895 | 767,895 | 446,304 | 61.7 | 187,165 | 594,427 | 12.8 | 96,201 | 354,023 | | |
| Missouri | 2,953,275 | 2,463,663 | 2,463,663 | 2,463,663 | | 584.5 | 699,562 | 158,005 | 216,652 | 177.3 | 77,547 | 343,679 | 55.2 | 20,238 | 1,226,765 | | |
| Montana | 1,859,531 | 942,934 | 1,814,177 | 1,813,058 | | 226.0 | 216,652 | | | | | | | 46,879 | 382,103 | | |
| Louisiana | 1,957,240 | 991,091 | 2,078,186 | 1,956,356 | | 339.8 | 470,756 | 470,756 | 470,756 | 93.9 | | 321,529 | 55.3 | 844 | 80,151 | | |
| Nevada | 1,156,479 | 852,000 | 1,232,741 | 1,112,162 | | 140.1 | 281,012 | 281,012 | 281,012 | 25.9 | | 20,000 | 10.0 | 24,317 | 475,716 | | |
| New Hampshire | 477,460 | 262,365 | 521,865 | 476,963 | | 25.6 | 85,607 | | 82,590 | 4.6 | | 57,479 | 3.4 | 497 | 102,296 | | |
| New Jersey | 55,099 | 460,000 | 55,099 | 55,099 | | 207.5 | 367,791 | 35,000 | 322,791 | 82.2 | 10,695 | 104,275 | 12.9 | | 460,000 | | |
| New Mexico | 1,272,818 | 755,534 | 1,272,818 | 1,272,818 | | 63.4 | 3,709,470 | 65,700 | 2,284,350 | 105.6 | | 1,247,368 | 120.3 | 25,250 | 218,399 | | |
| New York | 3,608,768 | 3,605,850 | 3,320,536 | 2,931,818 | | 24,200 | | | | | | | | | 359,332 | | |
| North Carolina | 2,360,573 | 1,590,637 | 2,006,317 | 2,005,539 | | 212.4 | 979,356 | 364,701 | 608,564 | 102.4 | | 391,717 | 36.7 | 10,333 | 590,355 | | |
| North Dakota | 1,451,112 | 734,741 | 895,842 | 895,842 | | 283.1 | 278,969 | 278,969 | 278,969 | 70.3 | 220,461 | 189,033 | 118.9 | 59,850 | 545,709 | | |
| Ohio | 3,471,148 | 1,966,253 | 4,095,935 | 3,767,315 | | 2,100 | 515,010 | 73,810 | 439,200 | 78.1 | | 384,170 | 22.4 | 30,023 | 1,340,783 | | |
| Oklahoma | 2,304,189 | 1,171,295 | 1,580,950 | 1,403,171 | | 206.0 | 1,186,172 | 780,867 | 104,086 | 16.4 | | 107,179 | 20.2 | 1,931 | 319,219 | | |
| Oregon | 1,526,784 | 777,096 | 1,709,157 | 1,407,198 | | 112.0 | 49,734 | 19,526 | 392,344 | 19.3 | | 273,269 | 16.7 | | 127,497 | | |
| Pennsylvania | 7,344,822 | 2,535,003 | 6,397,236 | 6,177,827 | | 942.8 | 2,463,900 | 1,162,995 | 1,446,425 | 204.8 | 4,000 | 686,102 | 18.0 | | 229,174 | | |
| Rhode Island | 433,716 | 295,000 | 414,250 | 404,748 | | 33.2 | 39,789 | 295,694 | 39,789 | 1.0 | | 222,350 | 5.6 | 34,948 | 32,860 | | |
| South Carolina | 1,452,479 | 981,719 | 1,116,909 | 1,060,296 | | 119.6 | 647,405 | 295,694 | 370,646 | 89.0 | | 265,840 | 33.3 | 46,882 | 619,567 | | |
| South Dakota | 1,502,479 | 981,719 | 1,116,909 | 1,060,296 | | 330.1 | 331,687 | 331,687 | | | 55,231 | 94,193 | 36.5 | | | | |
| Tennessee | 2,123,195 | 1,075,746 | 1,841,064 | 1,841,064 | | 102.6 | 1,122,787 | 834,756 | 288,031 | 61.9 | 4,503 | 149,662 | 4.9 | 73,694 | 618,095 | | |
| Texas | 3,012,518 | 3,638,000 | 5,876,171 | 5,450,782 | | 750.6 | 1,392,646 | 500,417 | 840,893 | 71.6 | 43,305 | 225,713 | 38.0 | 18,014 | 2,561,394 | | |
| Utah | 1,044,677 | 533,173 | 1,185,861 | 955,732 | | 185.6 | 238,999 | 92,845 | 108,000 | 40.4 | | 185,375 | 32.4 | | 129,000 | | |
| Vermont | 324,480 | 241,398 | 375,091 | 375,091 | | 77.2 | 118,931 | 107,965 | 113,066 | 8.4 | 21,267 | 94,956 | 7.0 | 1,718 | 16,183 | | |
| Virginia | 1,699,820 | 941,367 | 1,660,480 | 1,660,480 | | 105.6 | 439,041 | 107,965 | 326,375 | 37.0 | | 273,269 | 11.2 | 37,411 | 888,943 | | |
| Washington | 1,060,673 | 776,605 | 990,303 | 990,303 | | 62.5 | | | | | | | | 1,266 | 215,375 | | |
| West Virginia | 1,118,599 | 570,003 | 733,949 | 701,137 | | 41.9 | 359,084 | 359,084 | | | 25,237 | 178,802 | 4.9 | 33,101 | 391,281 | | |
| Wisconsin | 2,431,220 | 1,782,475 | 2,323,522 | 2,156,632 | | 170.4 | 491,865 | 202,460 | 232,448 | 15.1 | | 68,000 | 24.7 | 4,128 | 1,197,638 | | |
| Wyoming | 1,125,332 | 1,077,594 | 1,077,594 | 1,058,634 | | 146.5 | 90,037 | | 90,035 | 12.3 | 30,935 | 224,934 | 37.4 | 39,563 | 296,899 | | |
| District of Columbia | 950,234 | 730,362 | 1,071,502 | 931,842 | | 4.7 | 234,139 | | 234,139 | 2.6 | | 147,150 | 1.6 | 14,551 | 209,171 | | |
| Hawaii | 187,106 | 351,000 | 177,116 | 177,116 | | 4.9 | | | | | | | | 9,368 | 351,000 | | |
| TOTALS | 92,836,113 | 56,237,575 | 77,670,954 | 73,147,476 | | 7,997.9 | 36,604,450 | 17,430,942 | 16,961,542 | 3,011.0 | 1,184,903 | 14,787,495 | 1435.4 | 1,072,752 | 23,103,217 | | |

CURRENT STATUS OF UNITED STATES PUBLIC WORKS ROAD CONSTRUCTION

AS PROVIDED BY SECTION 204 OF THE NATIONAL INDUSTRIAL RECOVERY ACT (1934 FUNDS) AND BY THE ACT OF JUNE 18, 1934 (1935 FUNDS)

SUMMARY OF CLASSES 1, 2, AND 3.

AS OF JANUARY 31, 1935

| STATE | APPORTIONMENTS | | COMPLETED | | | UNDER CONSTRUCTION | | | APPROVED FOR CONSTRUCTION | | | BALANCE OF FUNDS AVAILABLE FOR NEW PROJECTS | |
|----------------------|---|-----------------------------------|--------------|-------------------------|-------------------------|----------------------|-------------------------|-------------------------|---------------------------|-------------------------|---------|---|-------------------------|
| | Sec. 204 of the Act of June 18, 1934 (1934 Funds) | Act of June 18, 1934 (1935 Funds) | Total Cost | 1934 Public Works Funds | 1935 Public Works Funds | Estimated Total Cost | 1934 Public Works Funds | 1935 Public Works Funds | 1934 Public Works Funds | 1935 Public Works Funds | Mileage | 1934 Public Works Funds | 1935 Public Works Funds |
| Alabama | \$ 4,370,133 | \$ 4,259,942 | \$ 7,017,604 | \$ 4,370,133 | \$ 4,259,942 | \$ 7,017,604 | \$ 4,370,133 | \$ 4,259,942 | \$ 4,370,133 | \$ 4,259,942 | 55.8 | \$ 268,247 | \$ 2,465,958 |
| Arizona | 5,211,960 | 2,641,375 | 5,500,699 | 5,211,960 | 2,641,375 | 5,500,699 | 5,211,960 | 2,641,375 | 5,211,960 | 2,641,375 | 25.5 | 61,098 | 1,507,605 |
| Arkansas | 6,744,335 | 3,428,949 | 5,197,072 | 6,744,335 | 3,428,949 | 5,197,072 | 6,744,335 | 3,428,949 | 6,744,335 | 3,428,949 | 80.6 | 206,955 | 1,962,229 |
| California | 15,607,394 | 7,932,206 | 16,418,562 | 15,607,394 | 7,932,206 | 16,418,562 | 15,607,394 | 7,932,206 | 15,607,394 | 7,932,206 | 59.2 | 31,606 | 4,689,468 |
| Colorado | 6,874,530 | 3,486,006 | 7,290,895 | 6,874,530 | 3,486,006 | 7,290,895 | 6,874,530 | 3,486,006 | 6,874,530 | 3,486,006 | 17.4 | 13,764 | 689,998 |
| Connecticut | 2,865,740 | 1,494,868 | 1,422,691 | 2,865,740 | 1,494,868 | 1,422,691 | 2,865,740 | 1,494,868 | 2,865,740 | 1,494,868 | 2.2 | 4,332 | 468,727 |
| Delaware | 1,819,048 | 923,395 | 1,618,107 | 1,819,048 | 923,395 | 1,618,107 | 1,819,048 | 923,395 | 1,819,048 | 923,395 | .7 | 4,323 | 227,891 |
| Florida | 2,661,343 | 2,661,343 | 5,370,464 | 2,661,343 | 2,661,343 | 5,370,464 | 2,661,343 | 2,661,343 | 2,661,343 | 2,661,343 | 23.5 | 108,562 | 1,548,684 |
| Georgia | 10,091,185 | 5,113,491 | 6,135,181 | 10,091,185 | 5,113,491 | 6,135,181 | 10,091,185 | 5,113,491 | 10,091,185 | 5,113,491 | 79.1 | 504,793 | 3,465,689 |
| Idaho | 4,466,249 | 2,877,466 | 4,615,766 | 4,466,249 | 2,877,466 | 4,615,766 | 4,466,249 | 2,877,466 | 4,466,249 | 2,877,466 | 20.2 | 44,819 | 1,231,853 |
| Illinois | 17,370,770 | 8,921,403 | 9,499,158 | 17,370,770 | 8,921,403 | 9,499,158 | 17,370,770 | 8,921,403 | 17,370,770 | 8,921,403 | 127.4 | 46,791 | 3,596,864 |
| Indiana | 10,571,845 | 5,088,965 | 6,355,160 | 10,571,845 | 5,088,965 | 6,355,160 | 10,571,845 | 5,088,965 | 10,571,845 | 5,088,965 | 98.6 | 35,312 | 3,899,819 |
| Iowa | 10,055,660 | 5,118,361 | 8,493,937 | 10,055,660 | 5,118,361 | 8,493,937 | 10,055,660 | 5,118,361 | 10,055,660 | 5,118,361 | 202.6 | 90,899 | 1,588,539 |
| Kansas | 10,093,604 | 5,117,675 | 9,354,080 | 10,093,604 | 5,117,675 | 9,354,080 | 10,093,604 | 5,117,675 | 10,093,604 | 5,117,675 | 14.6 | 23,009 | 1,210,665 |
| Kentucky | 3,818,311 | 3,818,311 | 7,636,622 | 3,818,311 | 3,818,311 | 7,636,622 | 3,818,311 | 3,818,311 | 3,818,311 | 3,818,311 | 14.0 | 553,101 | 956,246 |
| Louisiana | 5,628,591 | 2,963,912 | 3,712,696 | 5,628,591 | 2,963,912 | 3,712,696 | 5,628,591 | 2,963,912 | 5,628,591 | 2,963,912 | 6.5 | 188,927 | 2,270,233 |
| Maine | 3,359,917 | 1,711,586 | 3,214,295 | 3,359,917 | 1,711,586 | 3,214,295 | 3,359,917 | 1,711,586 | 3,359,917 | 1,711,586 | 97.6 | 13,491 | 973,668 |
| Maryland | 3,564,527 | 1,810,098 | 1,841,856 | 3,564,527 | 1,810,098 | 1,841,856 | 3,564,527 | 1,810,098 | 3,564,527 | 1,810,098 | 97.8 | 612,473 | 1,771,995 |
| Massachusetts | 6,391,100 | 3,350,474 | 3,793,874 | 6,391,100 | 3,350,474 | 3,793,874 | 6,391,100 | 3,350,474 | 6,391,100 | 3,350,474 | 60.9 | 469,974 | 2,206,348 |
| Michigan | 12,756,227 | 6,422,564 | 10,414,114 | 12,756,227 | 6,422,564 | 10,414,114 | 12,756,227 | 6,422,564 | 12,756,227 | 6,422,564 | 107.2 | 109,222 | 1,859,668 |
| Minnesota | 10,994,569 | 5,425,351 | 11,464,300 | 10,994,569 | 5,425,351 | 11,464,300 | 10,994,569 | 5,425,351 | 10,994,569 | 5,425,351 | 85.4 | 87,060 | 594,684 |
| Mississippi | 6,918,675 | 3,940,227 | 5,849,371 | 6,918,675 | 3,940,227 | 5,849,371 | 6,918,675 | 3,940,227 | 6,918,675 | 3,940,227 | 280.3 | 520,668 | 2,892,516 |
| Missouri | 12,140,326 | 6,173,740 | 9,652,656 | 12,140,326 | 6,173,740 | 9,652,656 | 12,140,326 | 6,173,740 | 12,140,326 | 6,173,740 | 103.4 | 405,062 | 2,899,306 |
| Montana | 7,439,748 | 3,769,734 | 8,140,340 | 7,439,748 | 3,769,734 | 8,140,340 | 7,439,748 | 3,769,734 | 7,439,748 | 3,769,734 | 182.4 | 8,796 | 2,709,011 |
| Nebraska | 7,024,941 | 3,924,124 | 8,053,087 | 7,024,941 | 3,924,124 | 8,053,087 | 7,024,941 | 3,924,124 | 7,024,941 | 3,924,124 | 117.2 | 34,558 | 246,730 |
| Nevada | 4,428,417 | 2,365,462 | 6,132,283 | 4,428,417 | 2,365,462 | 6,132,283 | 4,428,417 | 2,365,462 | 4,428,417 | 2,365,462 | 12.6 | 71,021 | 1,143,235 |
| New Hampshire | 1,999,439 | 969,462 | 1,866,134 | 1,999,439 | 969,462 | 1,866,134 | 1,999,439 | 969,462 | 1,999,439 | 969,462 | 8.7 | 71,961 | 185,435 |
| New Jersey | 6,346,019 | 3,220,479 | 4,151,613 | 6,346,019 | 3,220,479 | 4,151,613 | 6,346,019 | 3,220,479 | 6,346,019 | 3,220,479 | 3.0 | 28,294 | 2,617,177 |
| New Mexico | 5,792,935 | 2,941,700 | 5,615,281 | 5,792,935 | 2,941,700 | 5,615,281 | 5,792,935 | 2,941,700 | 5,792,935 | 2,941,700 | 22.0 | 101,594 | 960,004 |
| New York | 22,350,101 | 11,377,921 | 19,766,023 | 22,350,101 | 11,377,921 | 19,766,023 | 22,350,101 | 11,377,921 | 22,350,101 | 11,377,921 | 135.3 | 133,417 | 2,559,653 |
| North Carolina | 9,422,293 | 4,840,941 | 8,344,520 | 9,422,293 | 4,840,941 | 8,344,520 | 9,422,293 | 4,840,941 | 9,422,293 | 4,840,941 | 98.5 | 340,201 | 2,892,516 |
| North Dakota | 5,604,446 | 2,934,861 | 9,091,459 | 5,604,446 | 2,934,861 | 9,091,459 | 5,604,446 | 2,934,861 | 5,604,446 | 2,934,861 | 140.4 | 229,306 | 1,859,185 |
| Ohio | 15,464,592 | 7,865,012 | 16,100,528 | 15,464,592 | 7,865,012 | 16,100,528 | 15,464,592 | 7,865,012 | 15,464,592 | 7,865,012 | 63.2 | 290,691 | 2,709,011 |
| Oklahoma | 9,216,798 | 4,685,180 | 6,993,743 | 9,216,798 | 4,685,180 | 6,993,743 | 9,216,798 | 4,685,180 | 9,216,798 | 4,685,180 | 87.4 | 95,097 | 1,750,043 |
| Oregon | 6,146,496 | 3,595,188 | 15,379,422 | 6,146,496 | 3,595,188 | 15,379,422 | 6,146,496 | 3,595,188 | 6,146,496 | 3,595,188 | 32.2 | 28,796 | 956,921 |
| Pennsylvania | 16,931,604 | 8,931,223 | 14,811,572 | 16,931,604 | 8,931,223 | 14,811,572 | 16,931,604 | 8,931,223 | 16,931,604 | 8,931,223 | 66.7 | 146,619 | 1,128,694 |
| Rhode Island | 1,994,708 | 1,014,572 | 1,911,223 | 1,994,708 | 1,014,572 | 1,911,223 | 1,994,708 | 1,014,572 | 1,994,708 | 1,014,572 | 9.2 | 117,155 | 277,107 |
| South Carolina | 2,459,165 | 2,770,294 | 3,973,959 | 2,459,165 | 2,770,294 | 3,973,959 | 2,459,165 | 2,770,294 | 2,459,165 | 2,770,294 | 35.3 | 172,404 | 1,653,553 |
| South Dakota | 6,011,475 | 3,047,643 | 5,065,280 | 6,011,475 | 3,047,643 | 5,065,280 | 6,011,475 | 3,047,643 | 6,011,475 | 3,047,643 | 293.1 | 290,119 | 1,609,659 |
| Tennessee | 4,462,619 | 2,324,921 | 6,789,668 | 4,462,619 | 2,324,921 | 6,789,668 | 4,462,619 | 2,324,921 | 4,462,619 | 2,324,921 | 142.0 | 106,397 | 2,262,488 |
| Texas | 24,404,444 | 12,201,253 | 21,168,878 | 24,404,444 | 12,201,253 | 21,168,878 | 24,404,444 | 12,201,253 | 24,404,444 | 12,201,253 | 42.6 | 145,518 | 7,864,642 |
| Utah | 4,194,758 | 2,132,591 | 4,691,944 | 4,194,758 | 2,132,591 | 4,691,944 | 4,194,758 | 2,132,591 | 4,194,758 | 2,132,591 | 142.6 | 3,708 | 484,046 |
| Vermont | 1,467,573 | 944,007 | 1,907,445 | 1,467,573 | 944,007 | 1,907,445 | 1,467,573 | 944,007 | 1,467,573 | 944,007 | 13.4 | 6,444 | 177,993 |
| Virginia | 7,416,777 | 3,769,287 | 6,469,841 | 7,416,777 | 3,769,287 | 6,469,841 | 7,416,777 | 3,769,287 | 7,416,777 | 3,769,287 | 158.0 | 496,561 | 1,444,551 |
| Washington | 6,115,867 | 3,106,431 | 5,934,631 | 6,115,867 | 3,106,431 | 5,934,631 | 6,115,867 | 3,106,431 | 6,115,867 | 3,106,431 | 22.6 | 30,372 | 1,150,412 |
| West Virginia | 4,474,234 | 2,240,315 | 3,556,495 | 4,474,234 | 2,240,315 | 3,556,495 | 4,474,234 | 2,240,315 | 4,474,234 | 2,240,315 | 15.3 | 49,517 | 1,293,175 |
| Wisconsin | 4,941,837 | 2,280,339 | 9,284,399 | 4,941,837 | 2,280,339 | 9,284,399 | 4,941,837 | 2,280,339 | 4,941,837 | 2,280,339 | 95.4 | 114,642 | 2,780,439 |
| Wyoming | 4,501,357 | 2,281,712 | 4,995,022 | 4,501,357 | 2,281,712 | 4,995,022 | 4,501,357 | 2,281,712 | 4,501,357 | 2,281,712 | 134.6 | 51,543 | 51,543 |
| District of Columbia | 1,918,469 | 973,462 | 2,004,447 | 1,918,469 | 973,462 | 2,004,447 | 1,918,469 | 973,462 | 1,918,469 | 973,462 | 1.6 | 32,417 | 273,694 |
| Hawaii | 1,871,062 | 949,718 | 530,773 | 1,871,062 | 949,718 | 530,773 | 1,871,062 | 949,718 | 1,871,062 | 949,718 | 27.2 | 11,428 | 949,718 |
| TOTALS | 394,000,000 | 200,000,000 | 339,661,904 | 394,000,000 | 200,000,000 | 339,661,904 | 394,000,000 | 200,000,000 | 394,000,000 | 200,000,000 | 3,367.1 | 6,870,314 | 63,966,789 |

